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CONTRACT REPORT ARBRL-CR-00494

EVALUATION OF HANDGUNS AND LIGHTWEIGHT ARMOR

Prepared by

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This work serves largely as a supplement to that reported in Final Report, "Testing of Handguns," Contract No. DAAD05-76-C-0746, Task 4, July 22, 1977. Ten additional revolver models have been evaluated using the methods evolved in the previous work. In addition, some measurements were made on the ability of some steel and aluminum plates to withstand .38 Special "+P" and .357 Magnum revolver rounds at various angles of incidence.

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I. GENERAL

One intent of this work is to apply the methods of handgun evaluation developed under a prior contract to a number of commonly used handguns. These methods, the mode of presentation of data, and a discussion of the significance of the data is all well covered in the final report of the prior contract. (Cf. Final Report, "Testing of Handguns", Contract No. DAAD05-76-C-0746, Task 4, July 22, 1977.) In a sense, this report serves as an addendum to the prior report. The emphasis here is on obtaining a maximum of data at a relatively low cost (compared to the previous effort).

A second intent of this work is to evaluate steel and aluminum plates when used to defeat .38 Special "+P" and .357 Magnum ammunition fired at various angles of incidence. To add meaning to these measurements, velocity measurements were made on the above loads while using actual revolvers (instead of a more traditional Mann gun).

II. SELECTION OF HANDGUNS AND AMMUNITION

Table I lists the correlation between our internal control number, called "Gun Number", and the actual make, model, caliber, etc.

TABLE I

HANDGUNS EVALUATED

"Gun Number"	Identification
10	Colt, Detective Special, Model D1425 .38 Special, 2" barrel
19	Colt, Trooper Mark III, Model J4241 .357 Magnum, 4" barrel
43	Smith & Wesson, Model 64-1 (stainless steel) .38 Special, 4" barrel
46	Smith & Wesson, Model 66-4 (stainless steel) .357 Magnum, 4" barrel
71	Smith & Wesson, Model 19-3 .357 Magnum, 2½" barrel
86	Ruger, Police Service Six, Model SDA-34 .357 Magnum, 4" barrel
89	Ruger, Police Service Six, Model GF-84 (stainless steel) .38 Special, 4" barrel
95	Charter Arms, Target Bulldog, Model 43542 .357 Magnum, 4" barrel
98	Charter Arms, Police Bulldog, Model 53842 .38 Special, 4" barrel
99	Charter Arms, Police Bulldog, Model 53842 .38 Special, 4" barrel

TABLE I (CONT'D)

"Gun Number"	Identification
110	Dan Wesson, Model 15-24 .357 Magnum, 4" barrel
87	Ruger, Police Service Six, Model SDA-34 .357 Magnum, 4" barrel
90	Ruger, Police Service Six, Model GF-84 (stainless steel) .38 Special, 4" barrel

The table contains thirteen guns. The last two listed, no. 87 and no. 90, were used only for the velocity measurements described later. All the others went through destructive evaluation. One model, Charter Arms Model 53842, is listed twice. This is because the first sample of that model became inoperative during the firing tests, so we reran the tests with a second sample of that model, (no. 98 and no. 99, respectively). Details are discussed later.

Our choice of .38 Special "+P" ammunition was discussed completely in the prior work. We used Smith and Wesson "+P" 158 grain jacketed hollowpoint. Our choice for .357 Magnum ammunition was based on the data presented in the prior report combined with discussions on which type of round would most likely be popular. We used Smith and Wesson .357 Magnum 125 grain jacketed soft point.

III. EXPERIMENTAL APPROACH AND RESULTS

a. Static Pressure Measurements on the Cylinders.

The purpose of this test is to statically simulate the peak dynamic pressure which one particular chamber must withstand during the firing of a particular round. During this static simulation, we measure the strains created over each of the other chambers, as well as the one being pressurized. This test is carried out on each cylinder before firing 100 rounds, and then repeated to detect any change in response caused by the dynamic loading of firing. In all cases, the same chamber in each cylinder is pressurized and indeed the same chamber is used for each of the rounds fired. The details of the test and its method have been discussed previously (in the prior report). We used a 31,000 psi pressure to simulate the .38 Special round and a 38,000 psi pressure to simulate the .357 Magnum round. After the firing was completed, the "zeroes" of all the strain gages on all the cylinders were within about 0.4% of the largert measured strain, indicating very little shift in zero caused by the dynamic loading of firing. Table II shows the measured peak static strain for all the .38 caliber revolvers tested for both before and after firing. Table III shows the same for all the .357 revolvers. Note that one .357 revolver, the Charter Arms Target Bulldog (no. 95) has a five hole cylinder instead of six. Figures 1 through 11 show these strain measurements plotted to dramatize the assymmetry which seems to characterize these measurements. See prior report.

TABLE II

STATIC STRAIN MEASUREMENTS - .38 CALIBER

Gun number		CHAMBER 1	2	3	4	5	6
10	initially	2830 $\mu\epsilon$	240 $\mu\epsilon$	110 $\mu\epsilon$	0 $\mu\epsilon$	-50 $\mu\epsilon$	-250 $\mu\epsilon$
	after firing	2610	260	100	0	-30	-280
43	initially	1740	270	130	10	-50	-200
	after firing	1770	270	120	10	-60	-220
89	initially	2230	140	100	20	-50	-180
	after firing	2200	150	90	40	-50	-170
98	initially	3430	340	160	70	-50	-310
	after firing*	3260	370	150	60	-40	-280
99	initially	1870	390	200	70	-30	-240
	after firing	1920	380	170	70	-60	-240

* Gun number 98 fired only 70 rounds before the grip frame broke in our grip holder. This destroyed the mainspring seat, thus making the weapon inoperative. We modified the grip holder to provide more cushioning, and had no trouble with Gun no. 99. However, the original arrangement worked fine with the other handguns tested.

TABLE III

STATIC STRAIN MEASUREMENTS - .357 MAGNUM

Gun number		CHAMBER 1	2	3	4	5	6
19	initially	1890$\mu\epsilon$	110$\mu\epsilon$	20$\mu\epsilon$	10$\mu\epsilon$	-30$\mu\epsilon$	-180$\mu\epsilon$
	after firing	1970	120	20	20	-40	-190
46	initially	2740	200	80	20	-60	-220
	after firing	2670	190	90	30	-80	-220
71	initially	2810	290	100	30	-40	-230
	after firing	2790	300	110	50	-60	-240
86	initially	2660	170	70	20	-60	-200
	after firing	2720	200	80	20	-80	-230
95	initially	3240	20	60	-40	-160	
	after firing*	1800	0	40	-30	-160	
110	initially	2270	190	30	30	-30	-220
	after firing	2240	190	20	20	-30	-220

* Gun number 95 was the only gun which lost a strain gage during firing. The strain gage over the firing chamber (the one being pressurized) had to be replaced. Note that this gun has only five chambers in the cylinder.

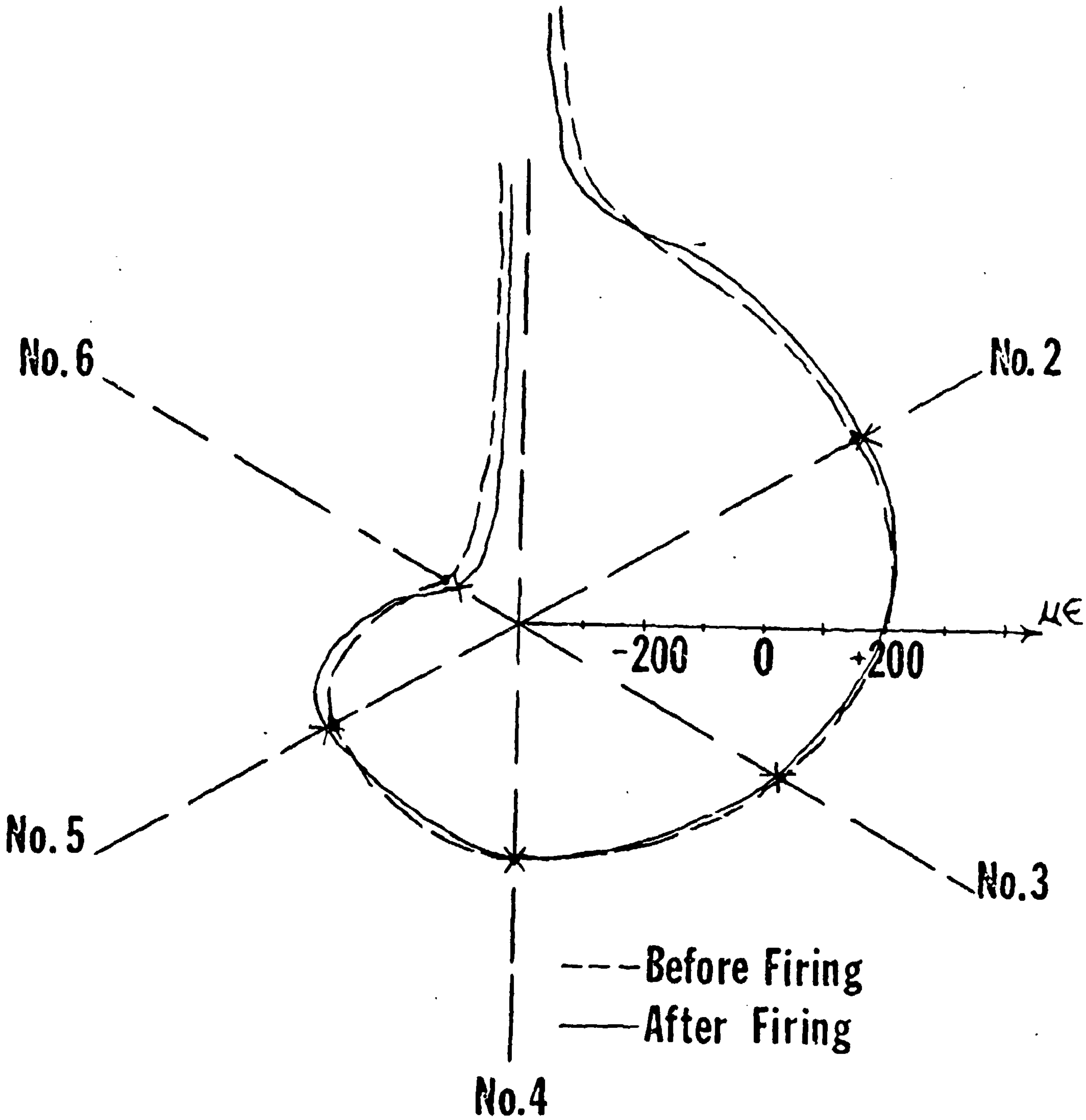

Figure 1. Strain Measurements on Gun no. 10.

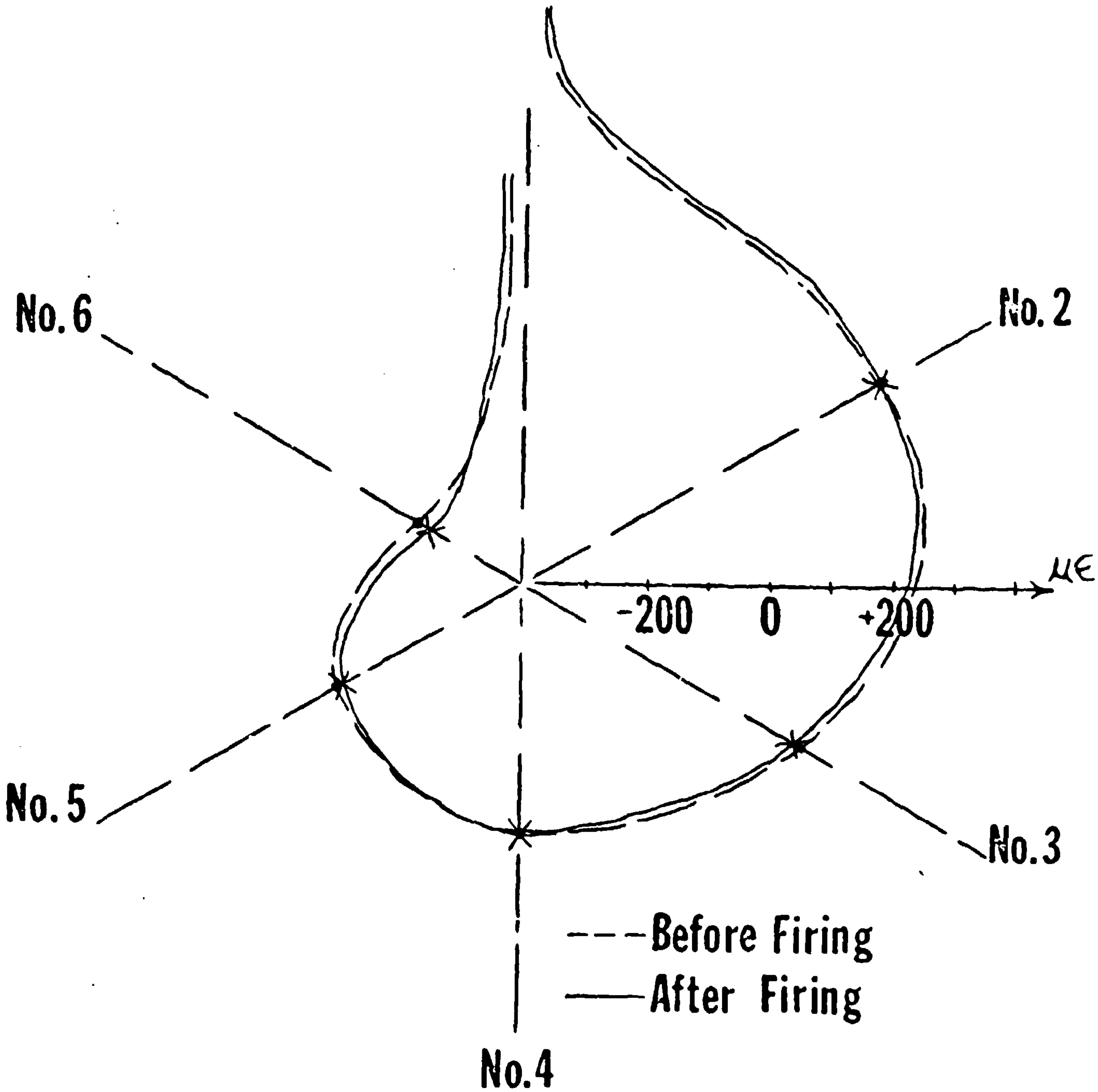

Figure 2. Strain Measurements on Gun no. 43.

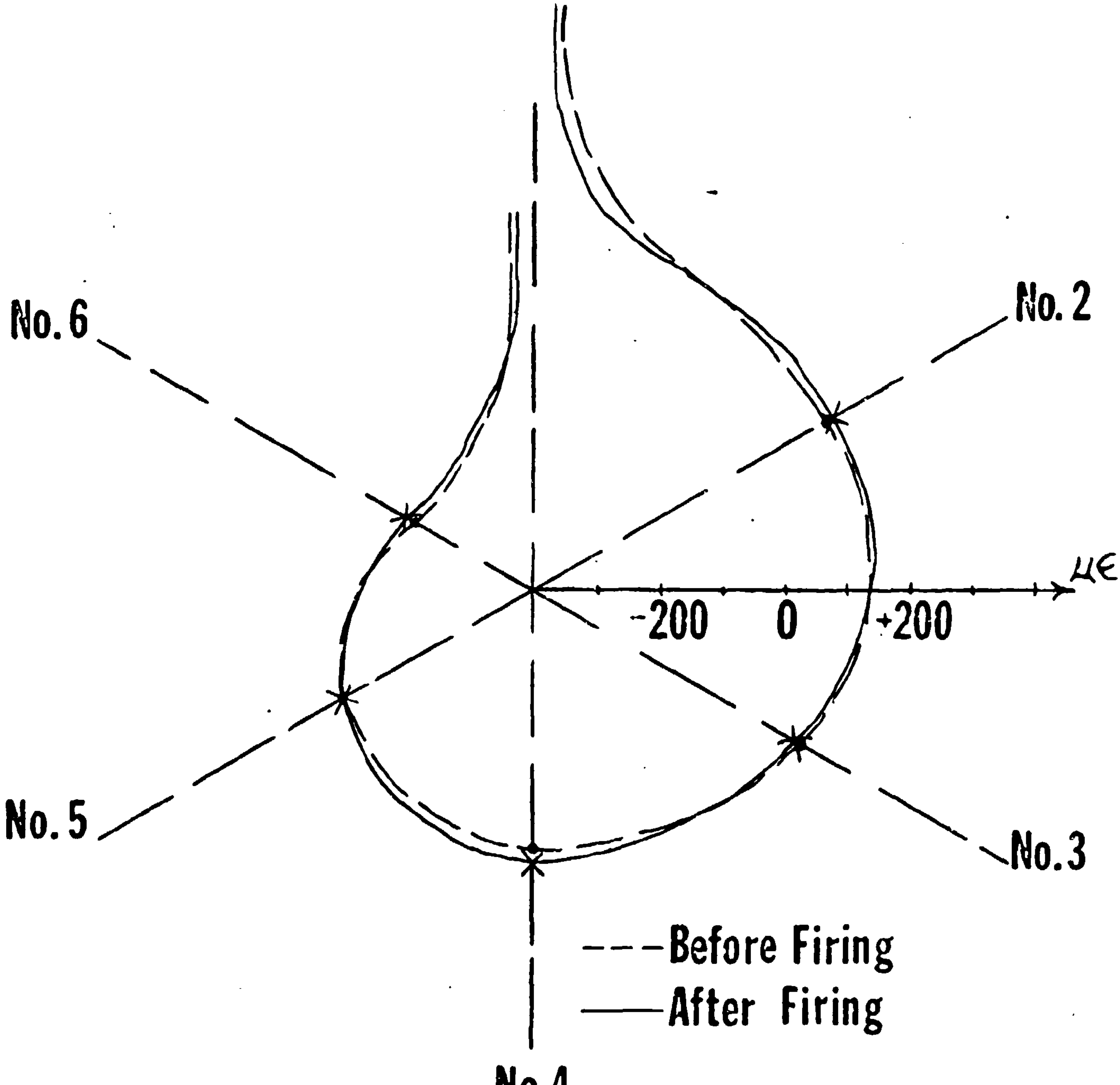

Figure 3. Strain Measurements on Gun no. 89.

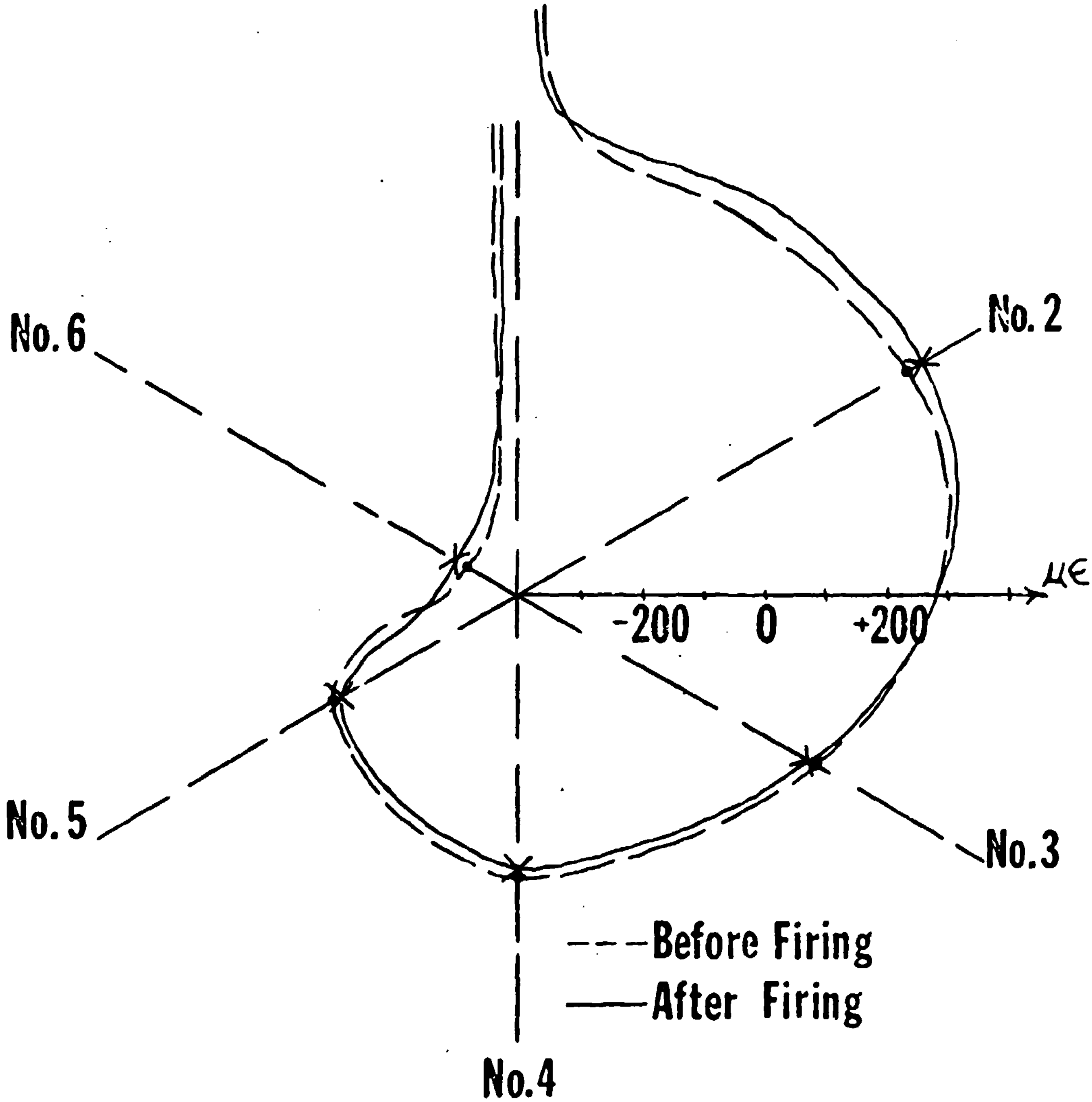

Figure 4. Strain Measurements on Gun no. 98.

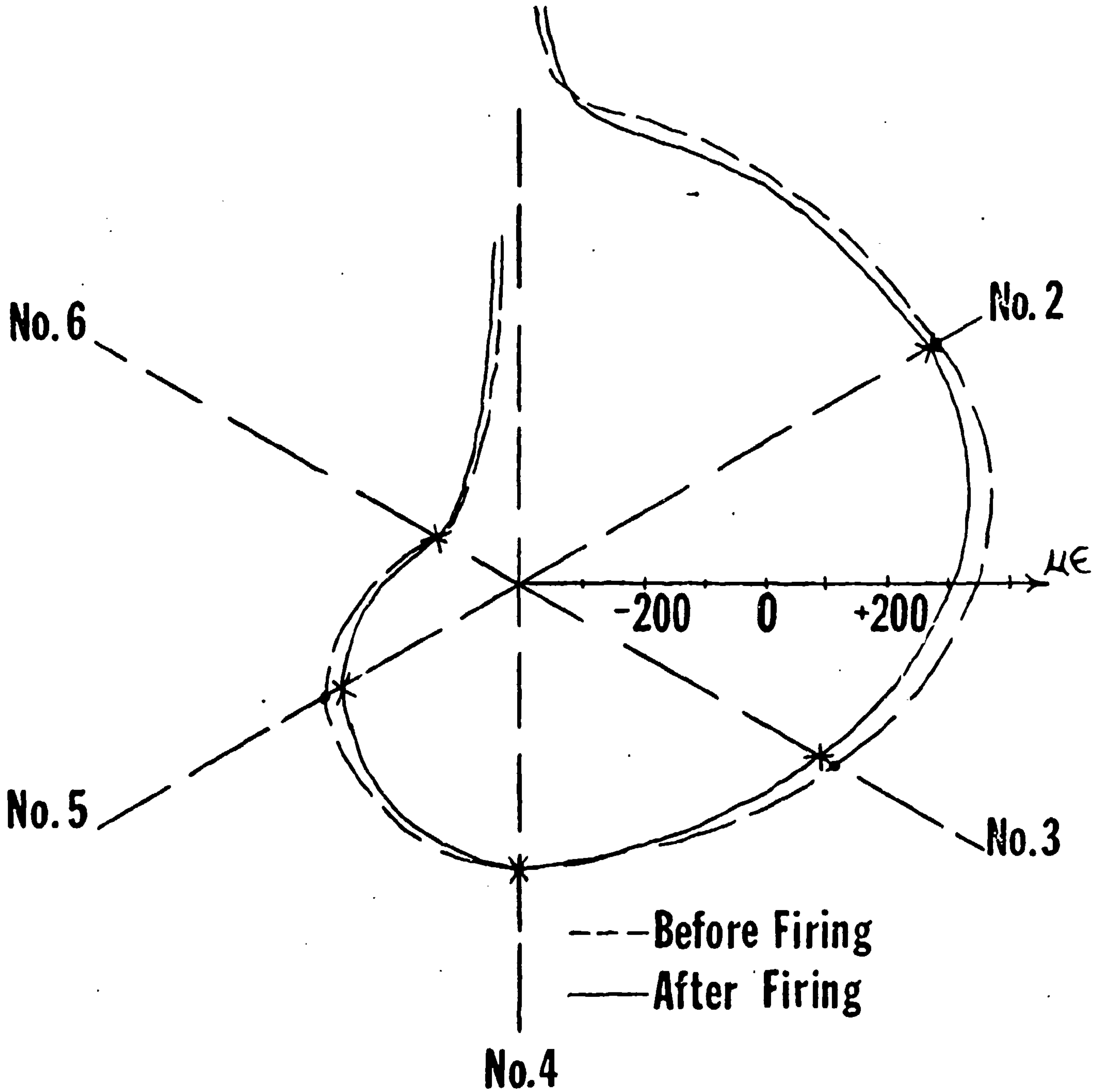

Figure 5. Strain Measurements on Gun no. 99.

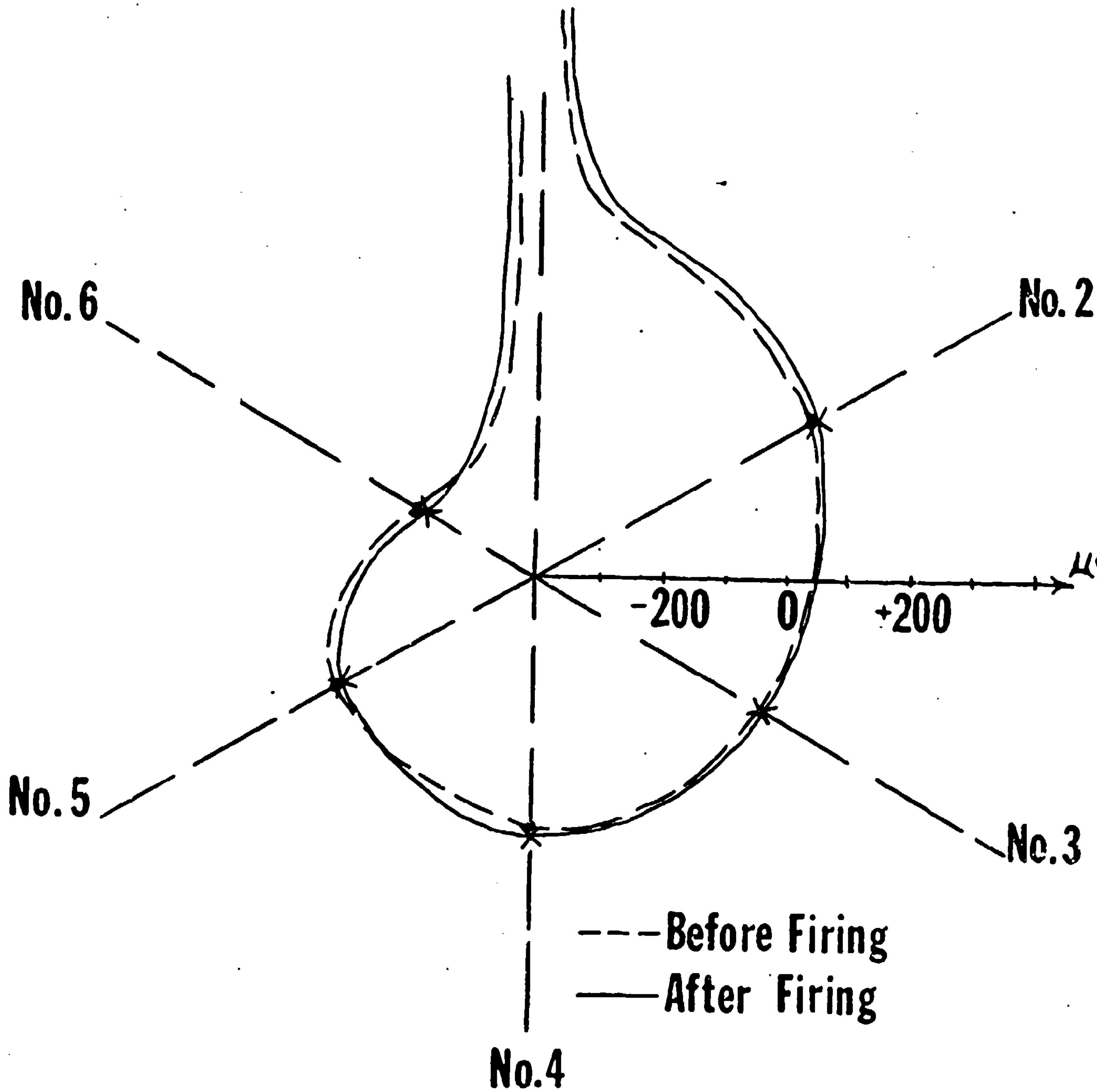

Figure 6. Strain Measurements on Gun no. 19.

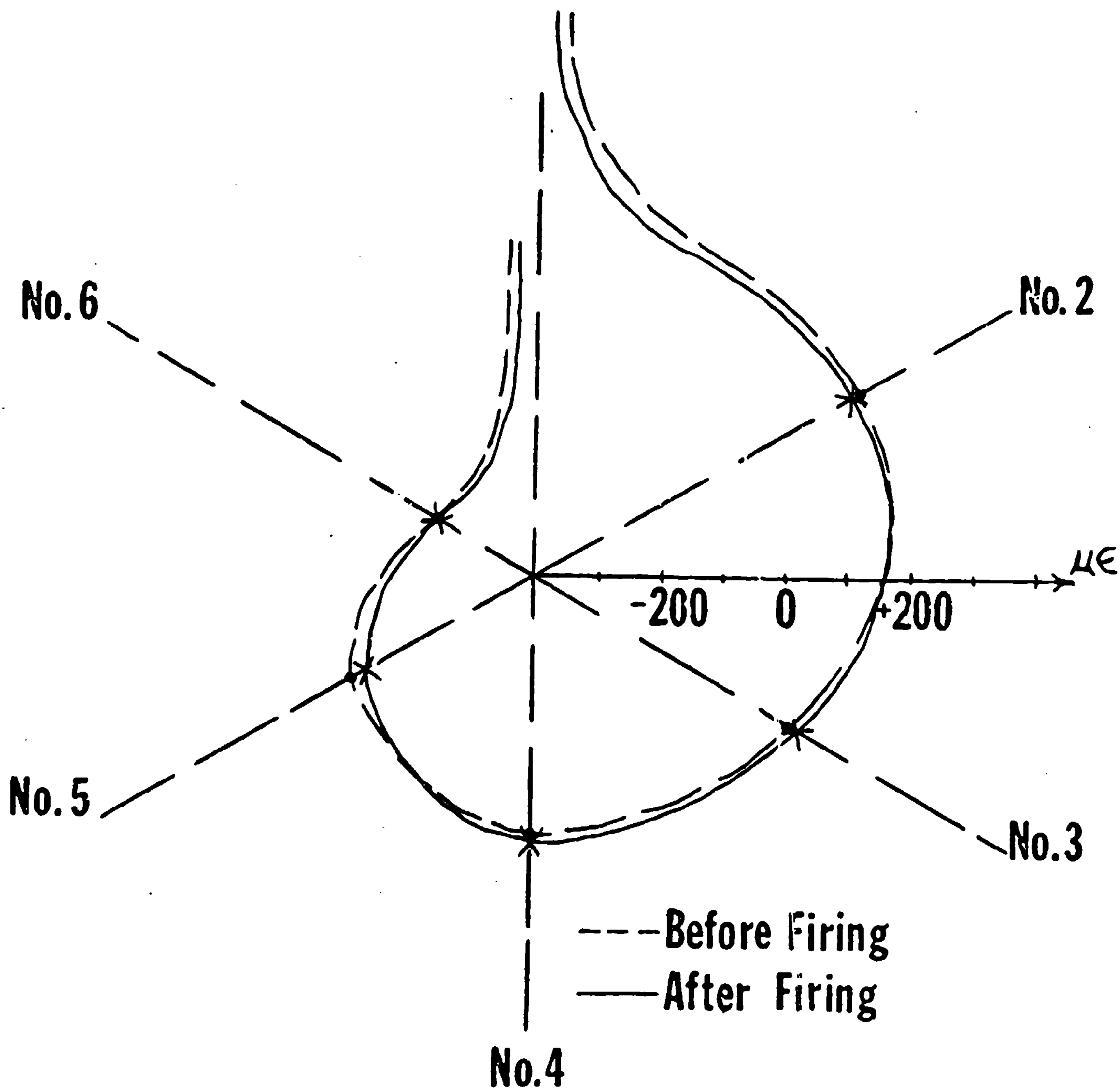

Figure 7. Strain Measurements on Gun no. 46.

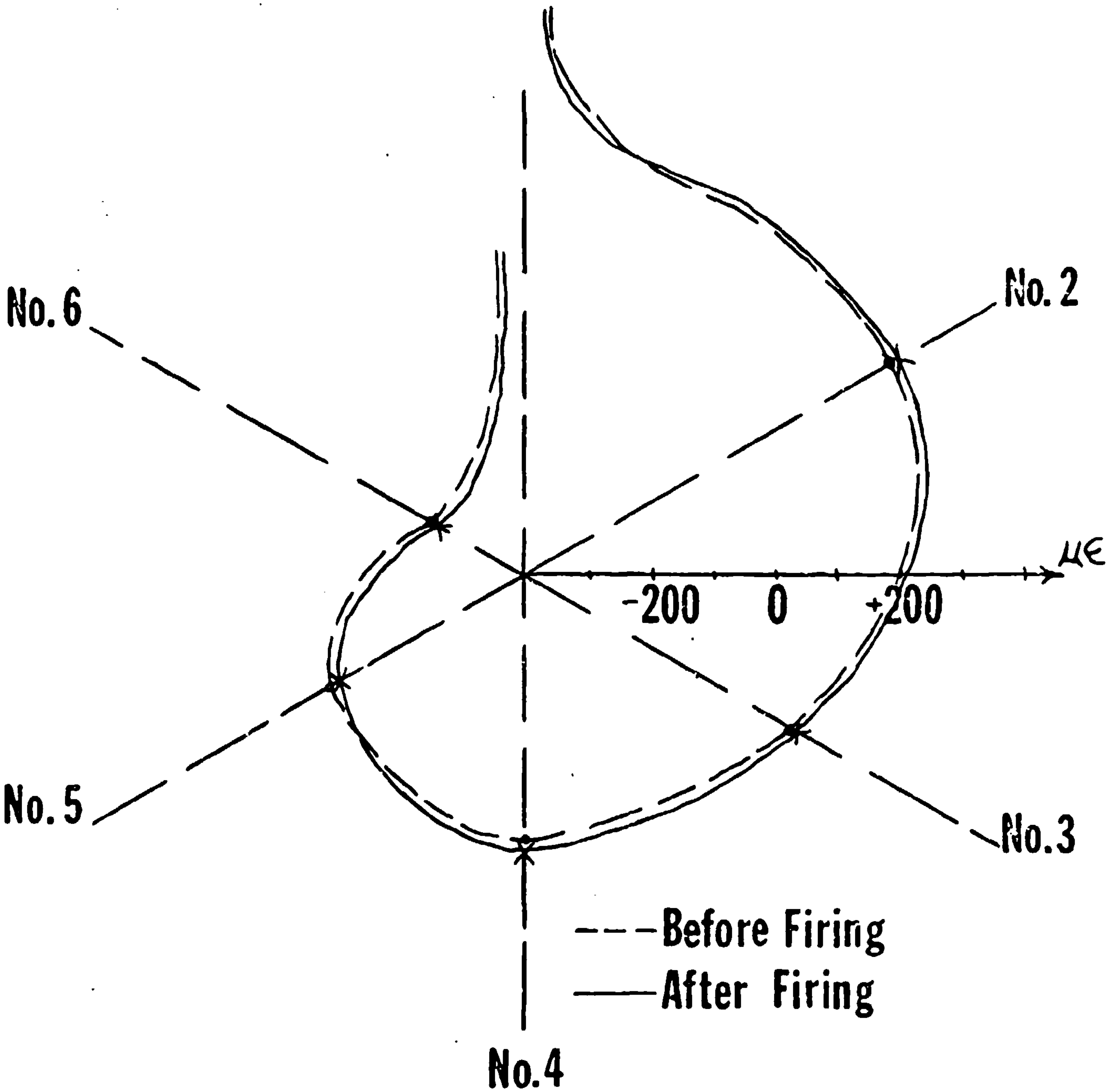

Figure 8. Strain Measurements on Gun no. 71.

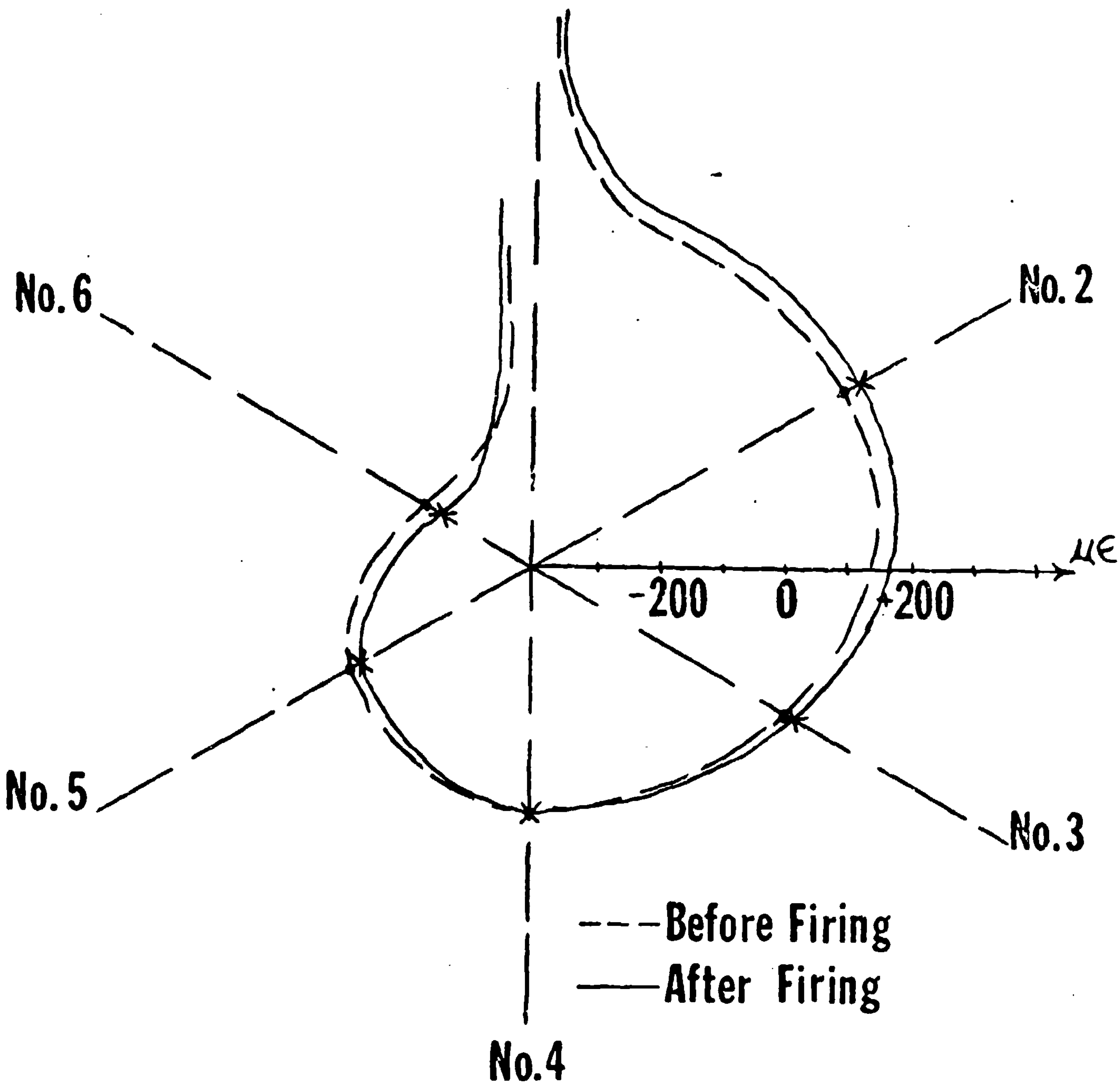

Figure 9. Strain Measurements on Gun no. 86.

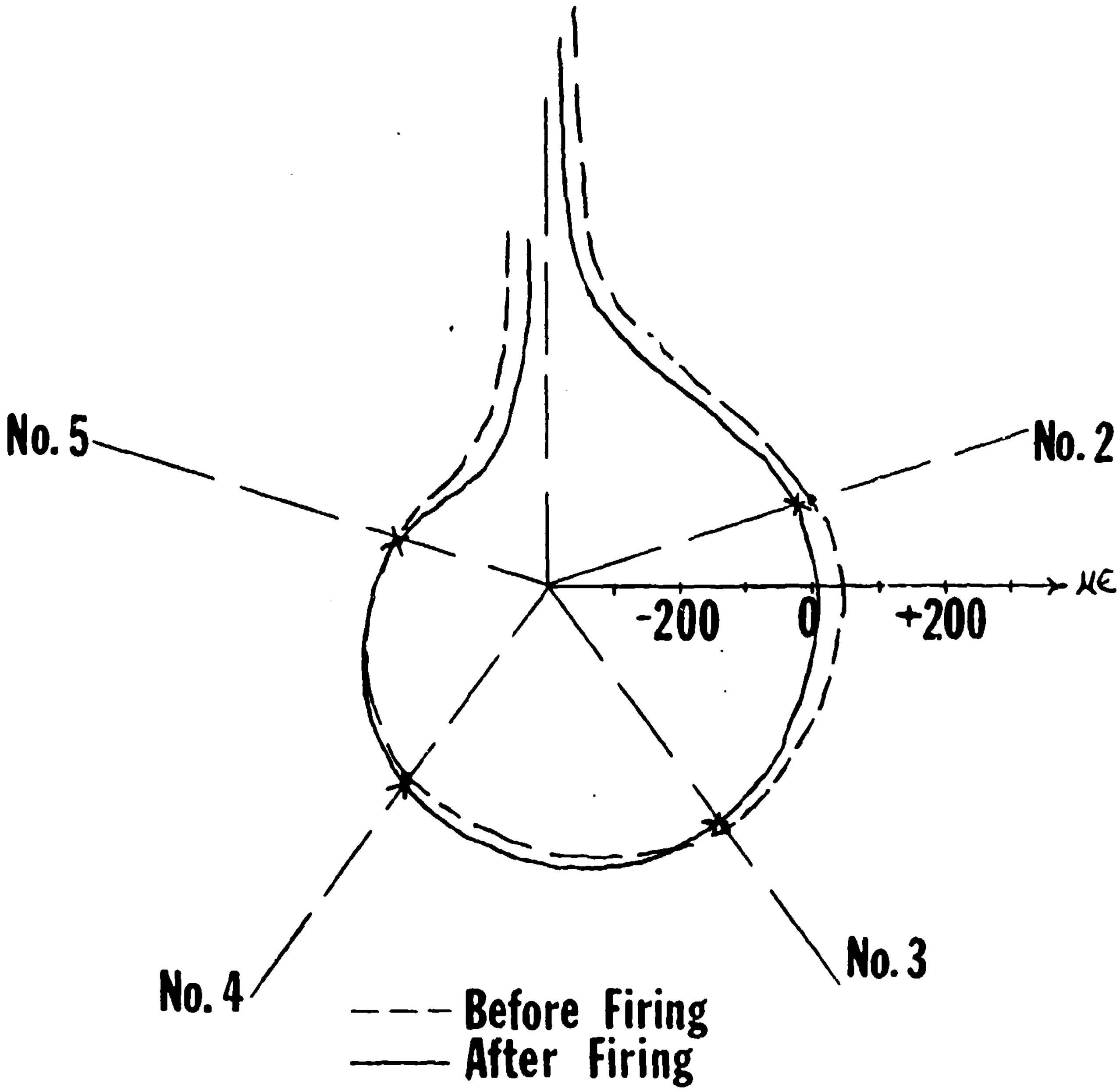

Figure 10. Strain Measurements on Gun no. 95.

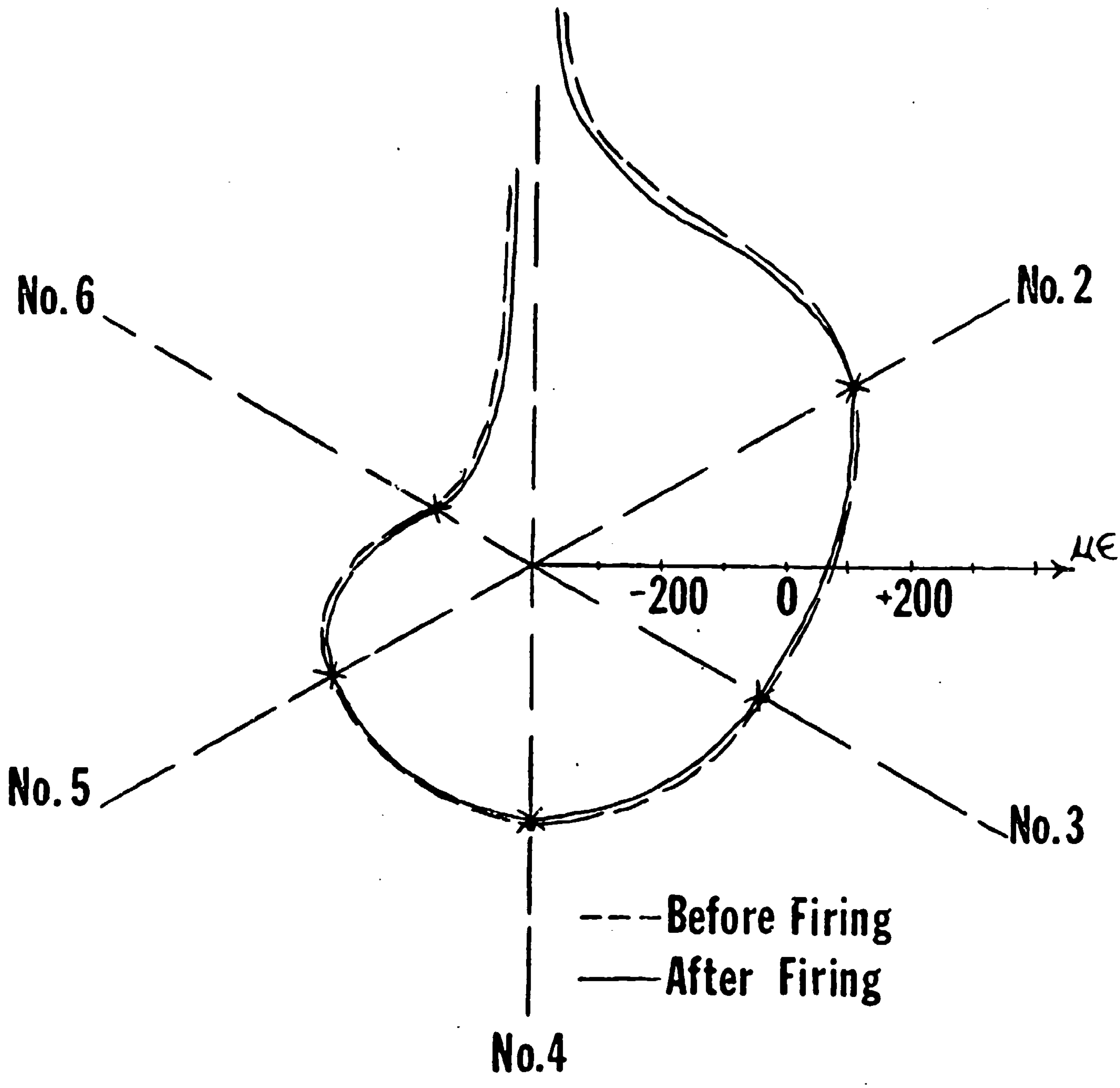

Figure 11. Strain Measurements on Gun no. 110.

b. Eddy Current Detector Measurements on the Recoil Plates.

The eddy current measurement of deformation in recoil plates was continued in this work as described in the prior report. The recoil plates were scanned in orthagonal paths athwart and vertical to the guns. Again the edge of the recoil plates and the firing pin holes generally saturate the instrument in the mode of measurement selected. The measurement of interest is in the area between the plate edge and the firing pin hole. The plates were scanned to establish initial measurements, and then were remeasured on each gun after each five rounds were fired. A total of one hundred rounds were fired for each gun. Figures 12 through 33 show the resulting data for both horizontal and vertical scans of each gun tested.

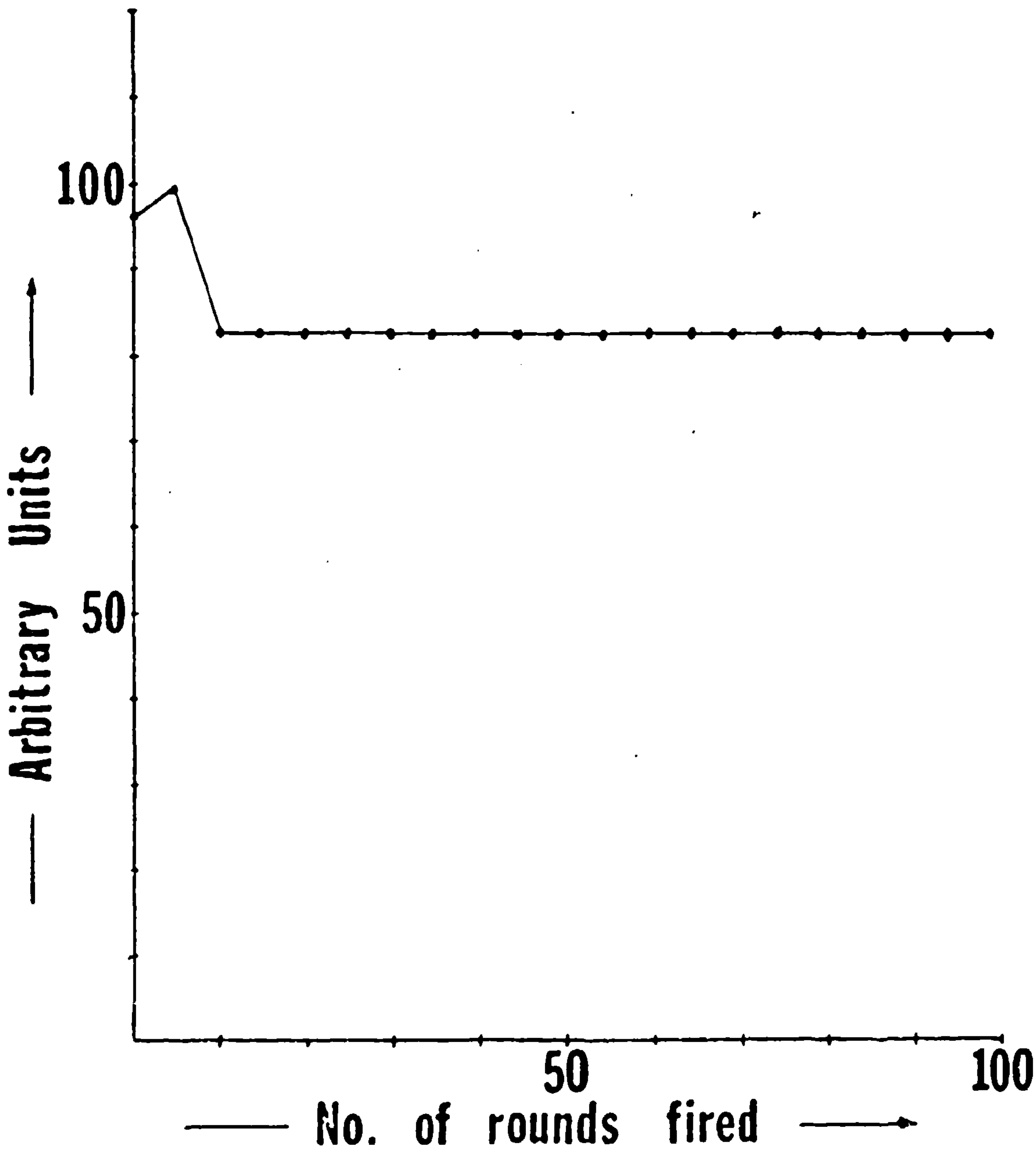

Figure 12. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 10.

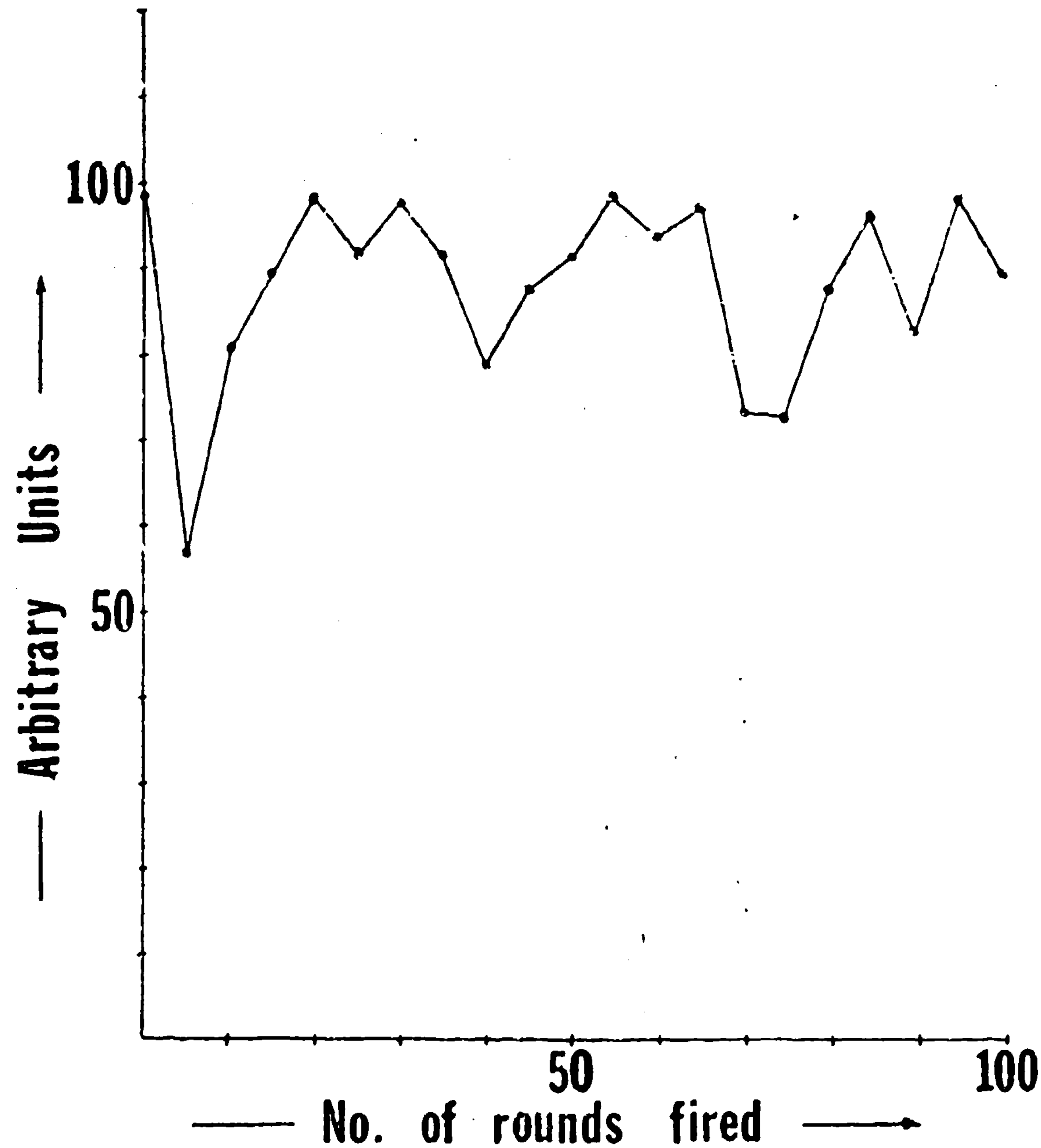

Figure 13. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 10.

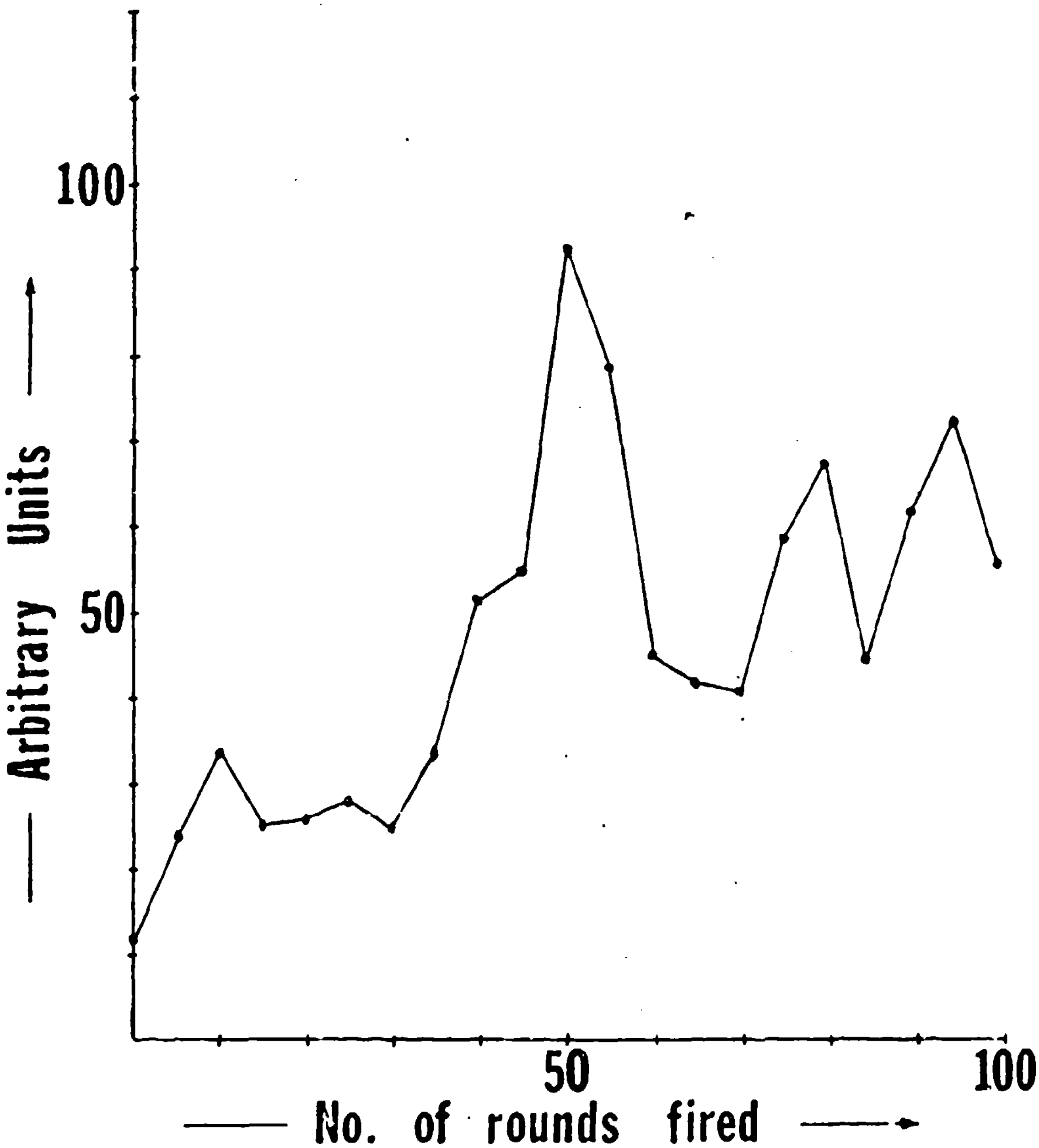

Figure 14. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 43.

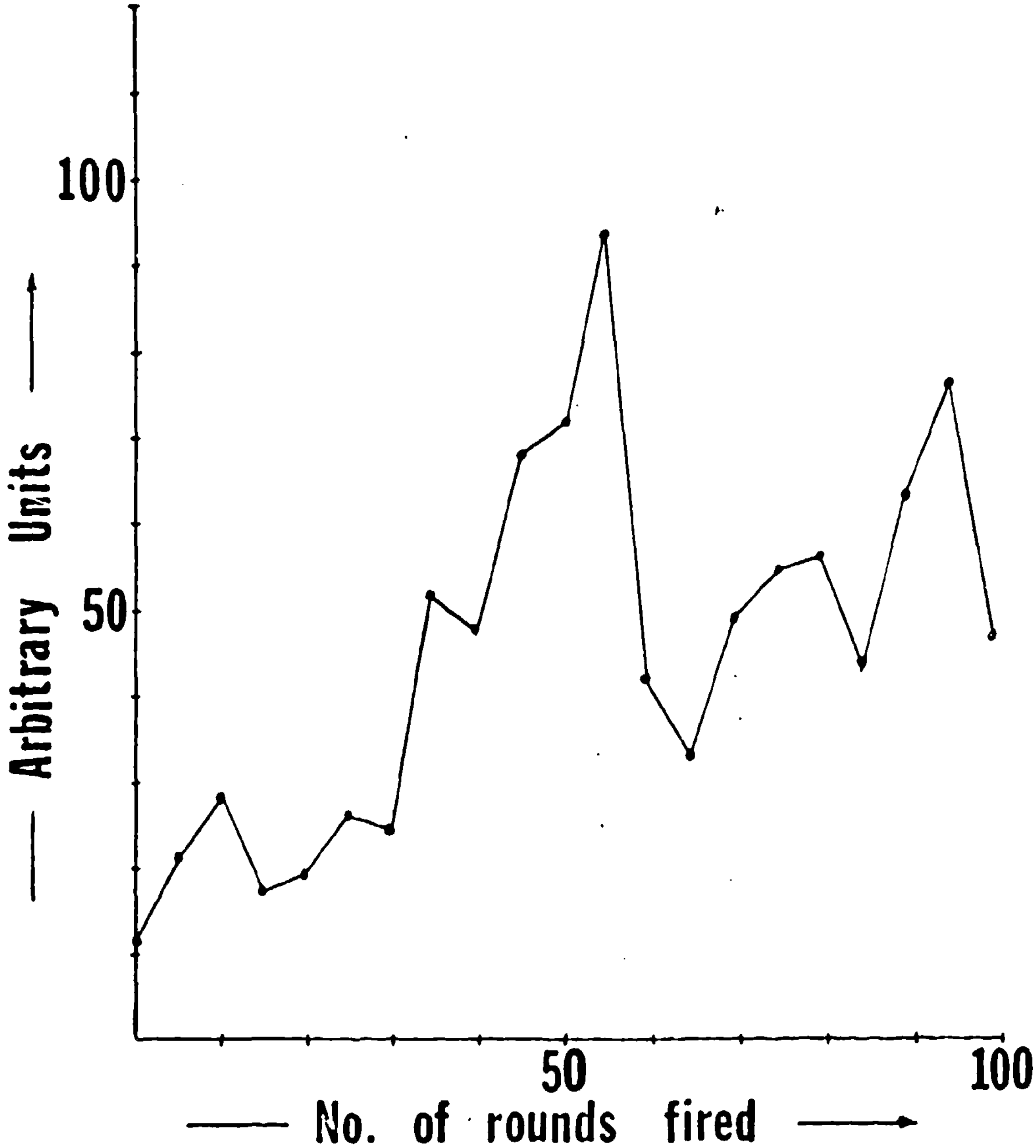

Figure 15. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 43.

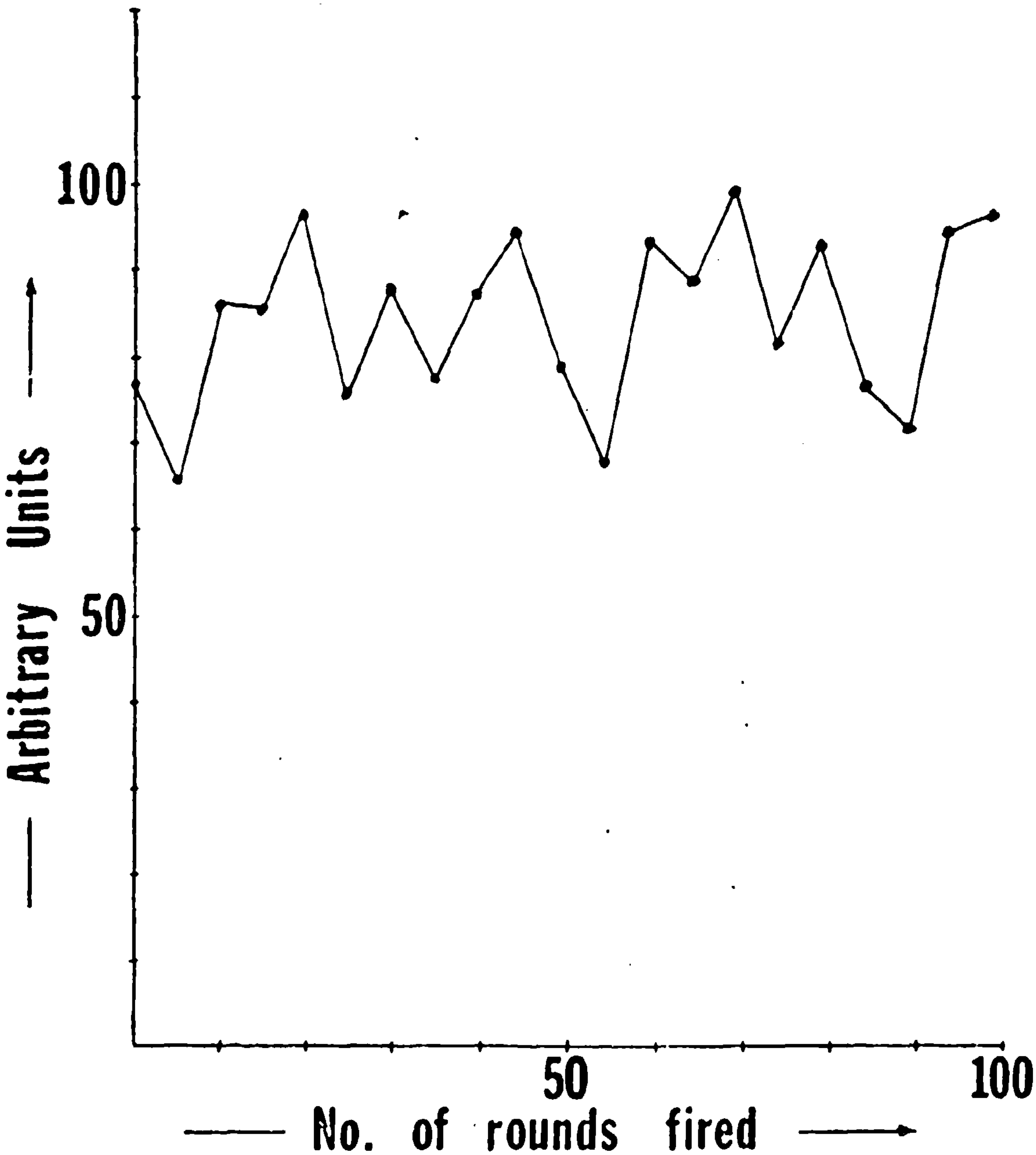

Figure 16. Detector Output vs. Rounds Fired for Atonart Scan of Gun no. 89.

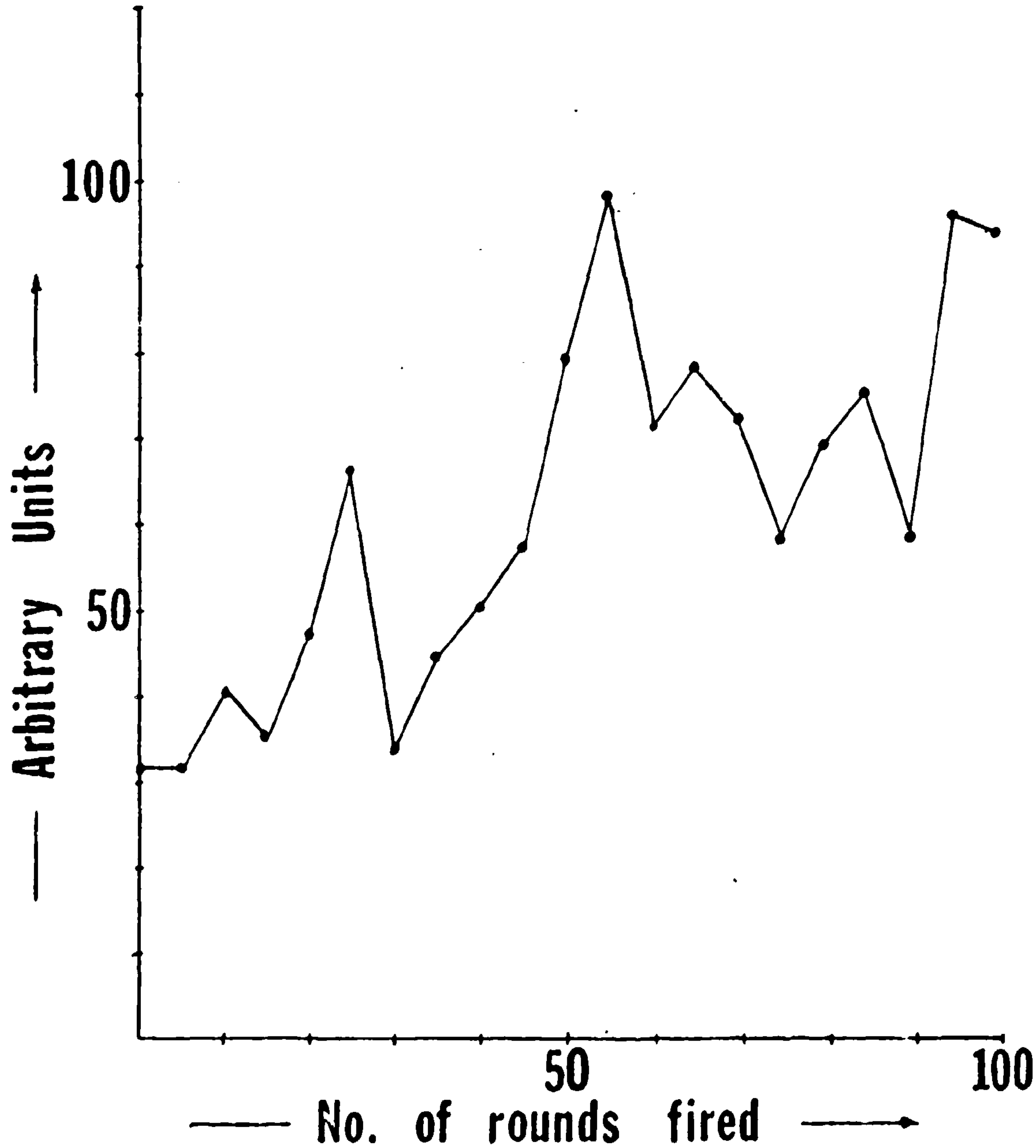

Figure 17. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 89.

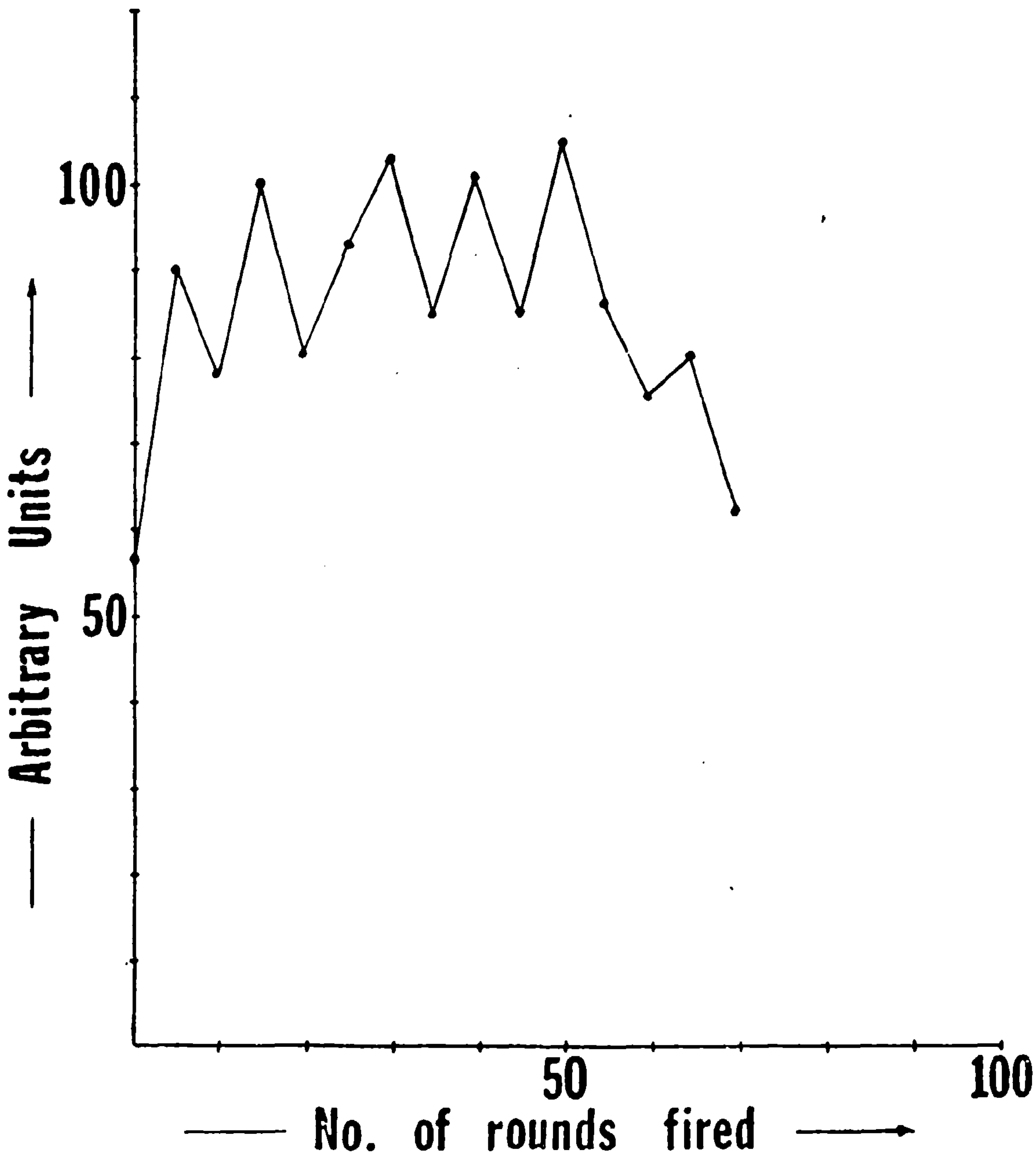

Figure 18. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 98.

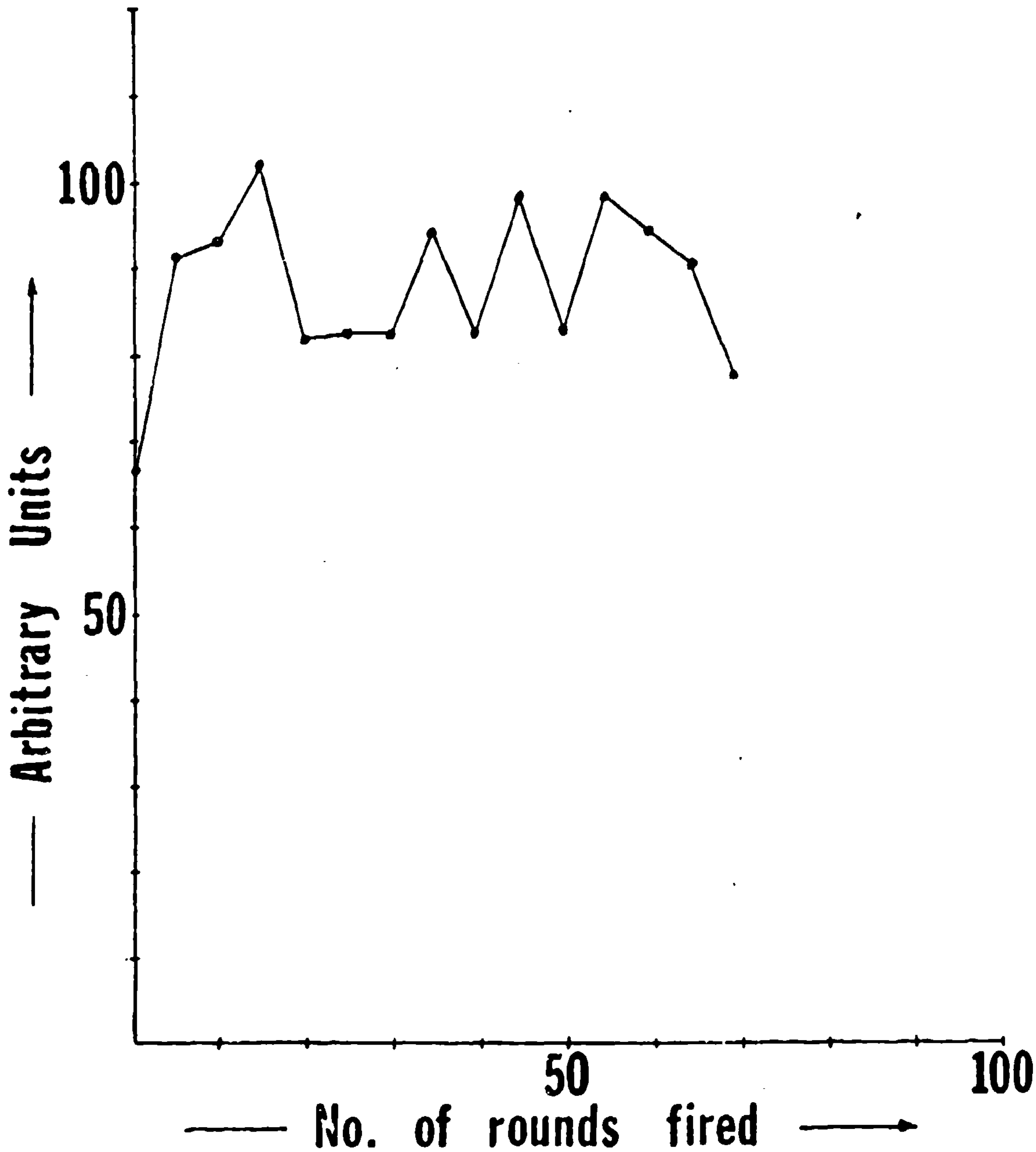

Figure 19. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 98.

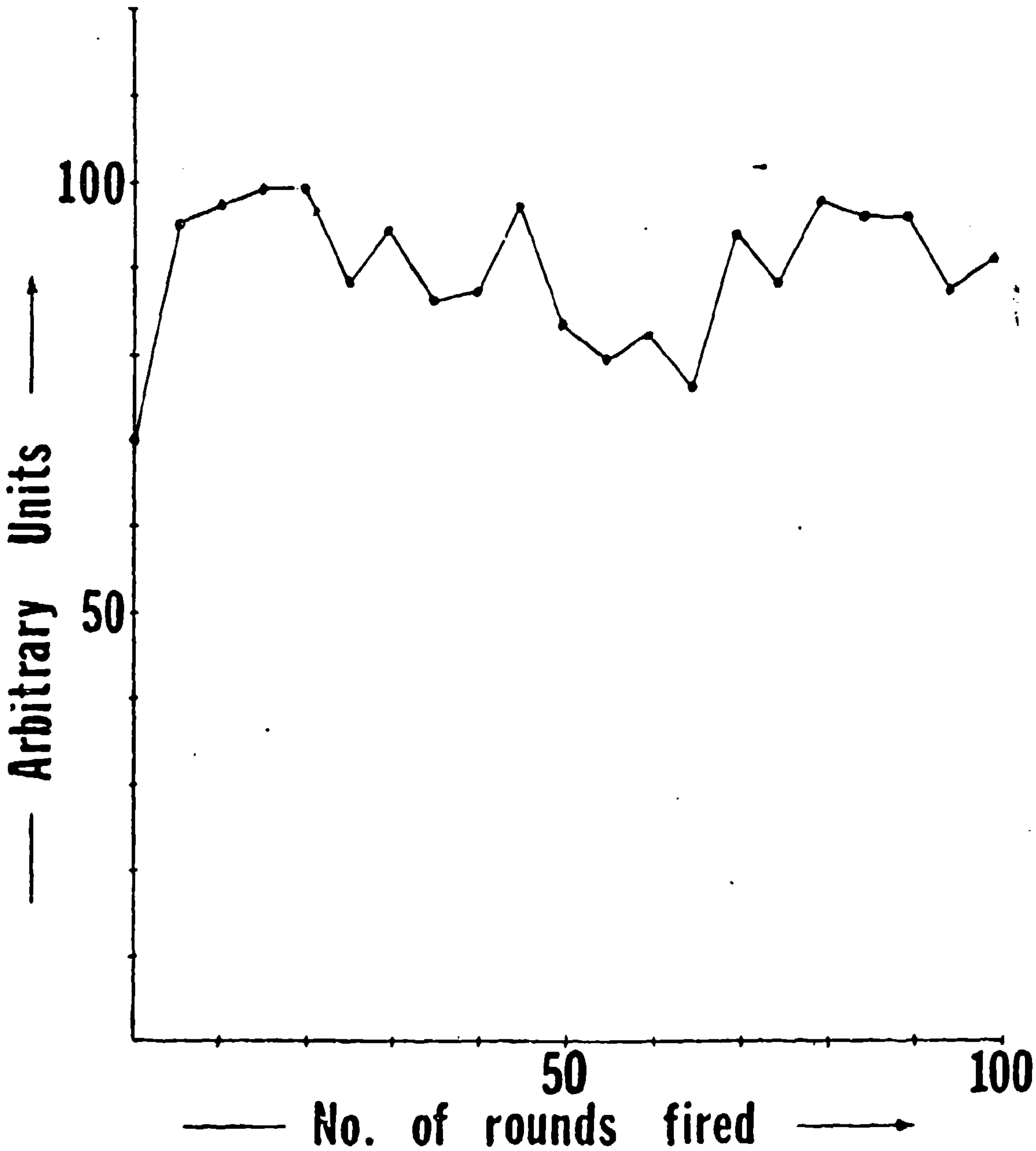

Figure 20. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 99.

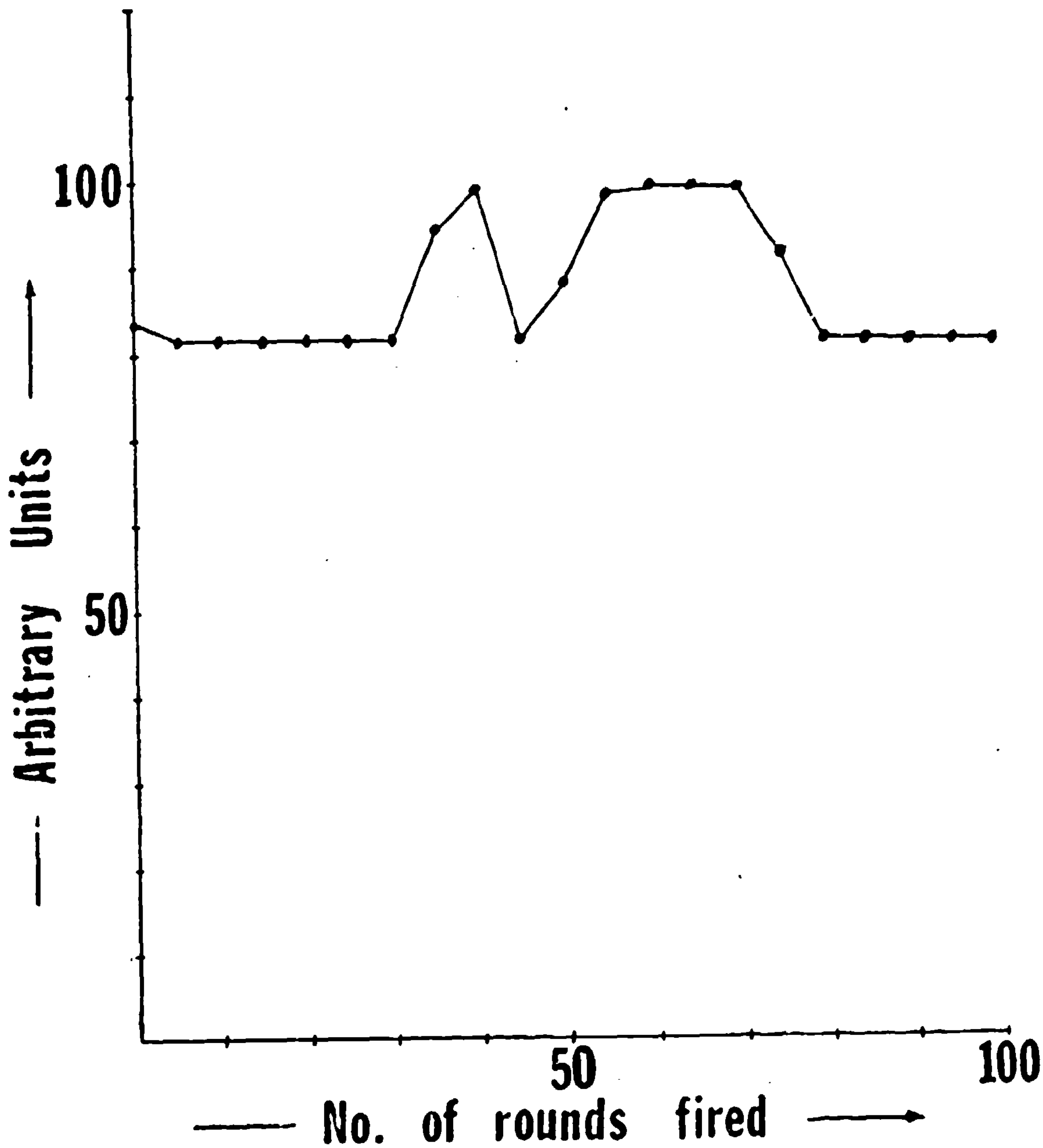

Figure 21. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 99.

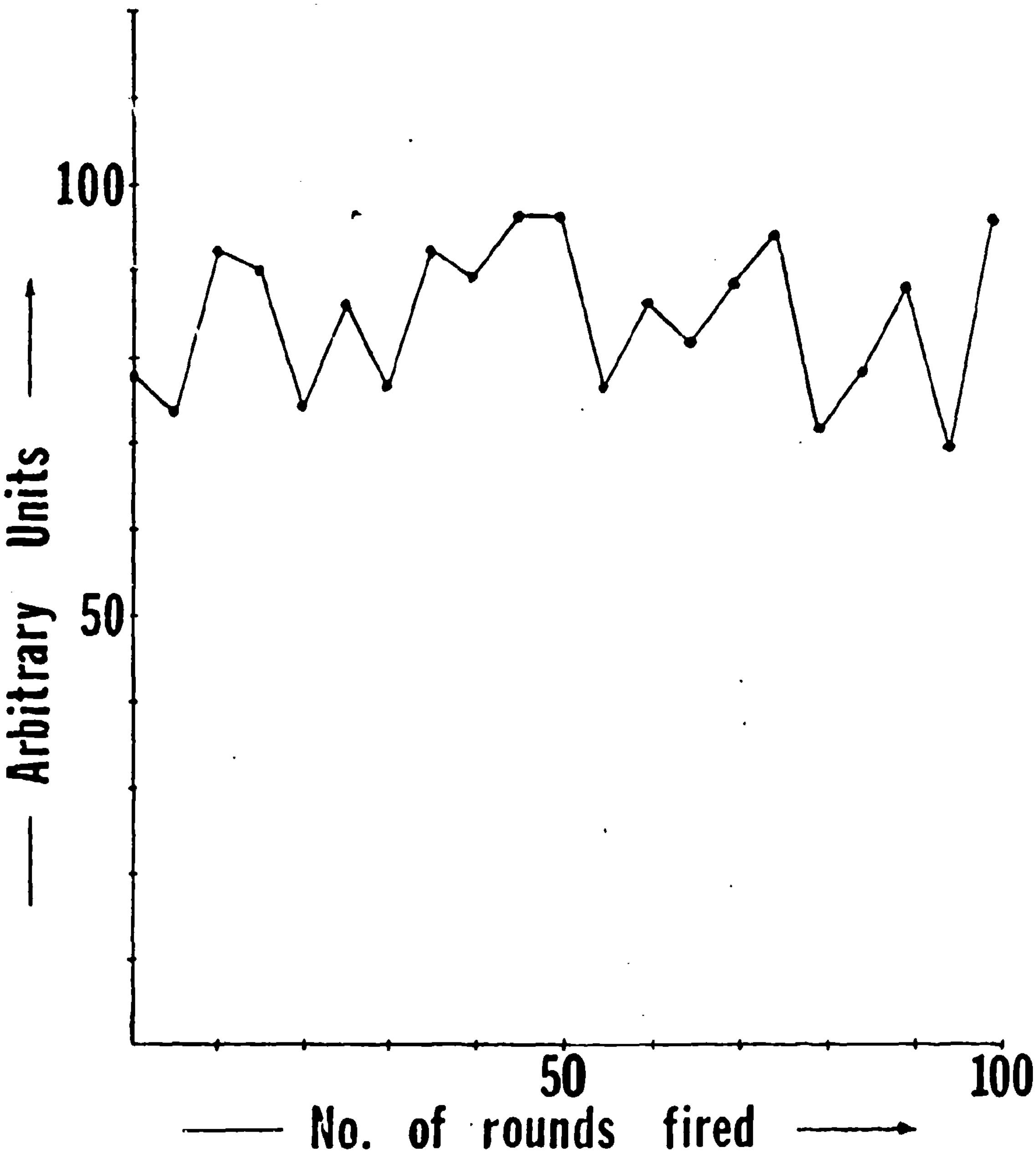

Figure 22. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 19.

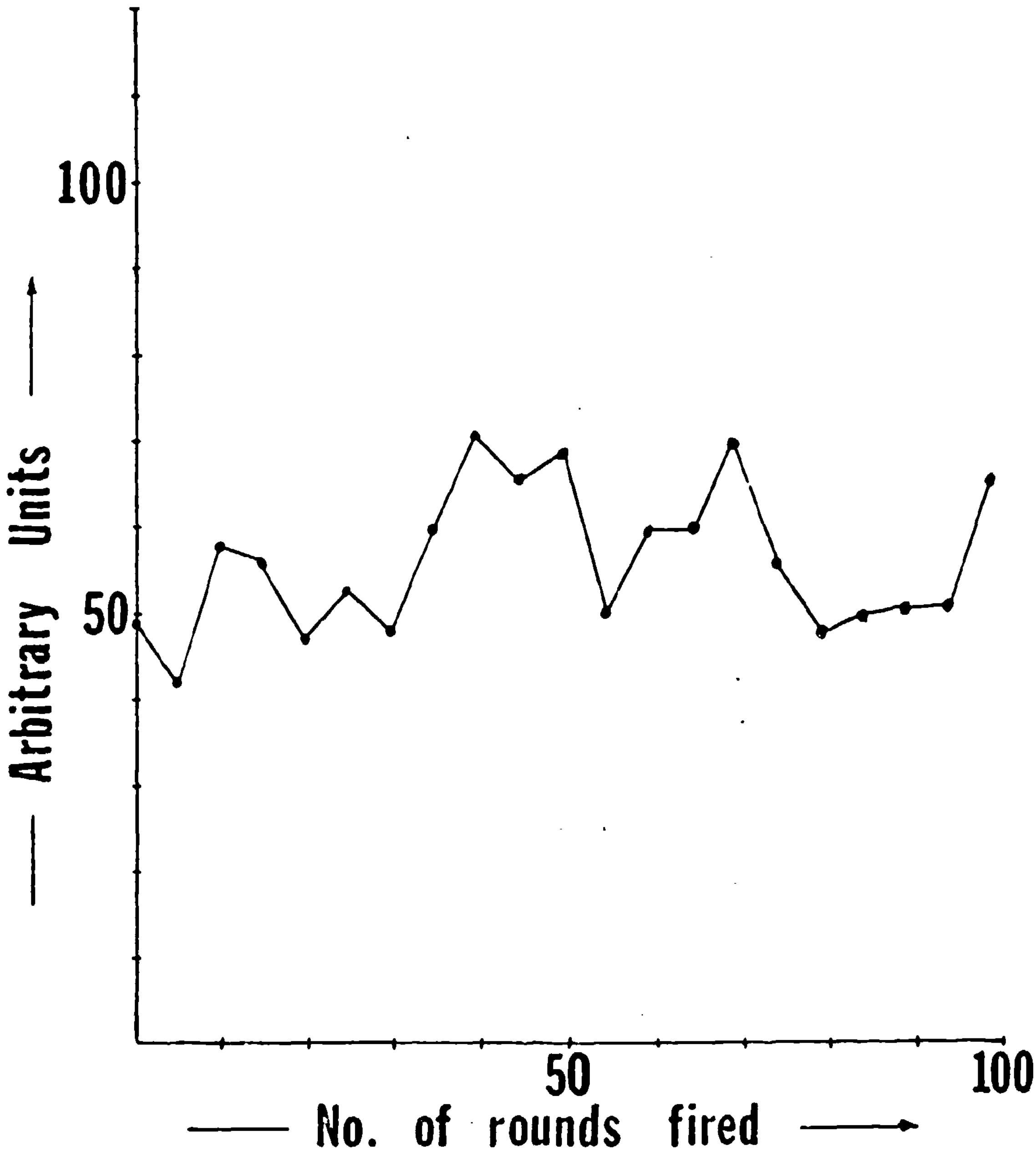

Figure 23. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 19.

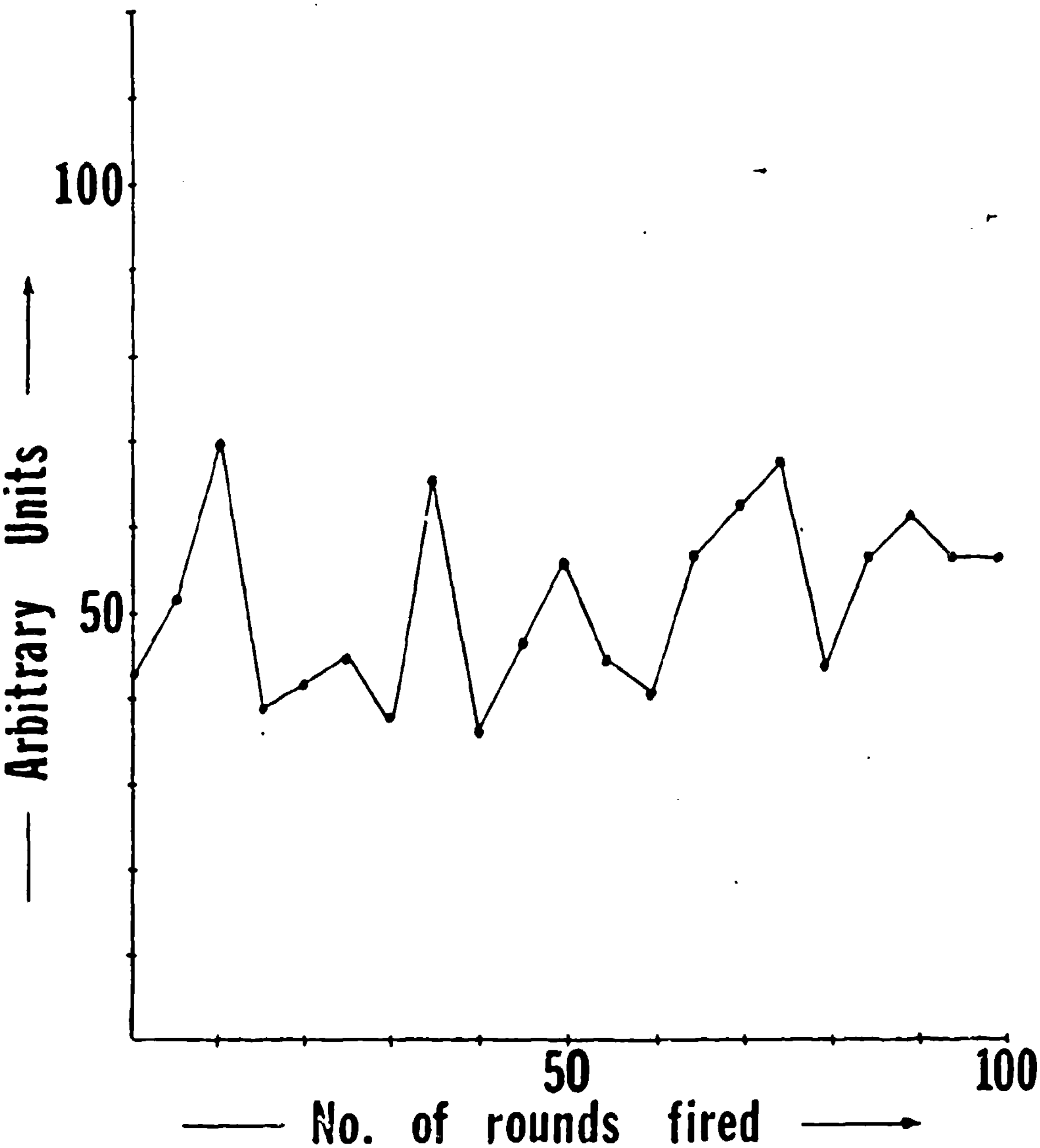

Figure 24. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 46.

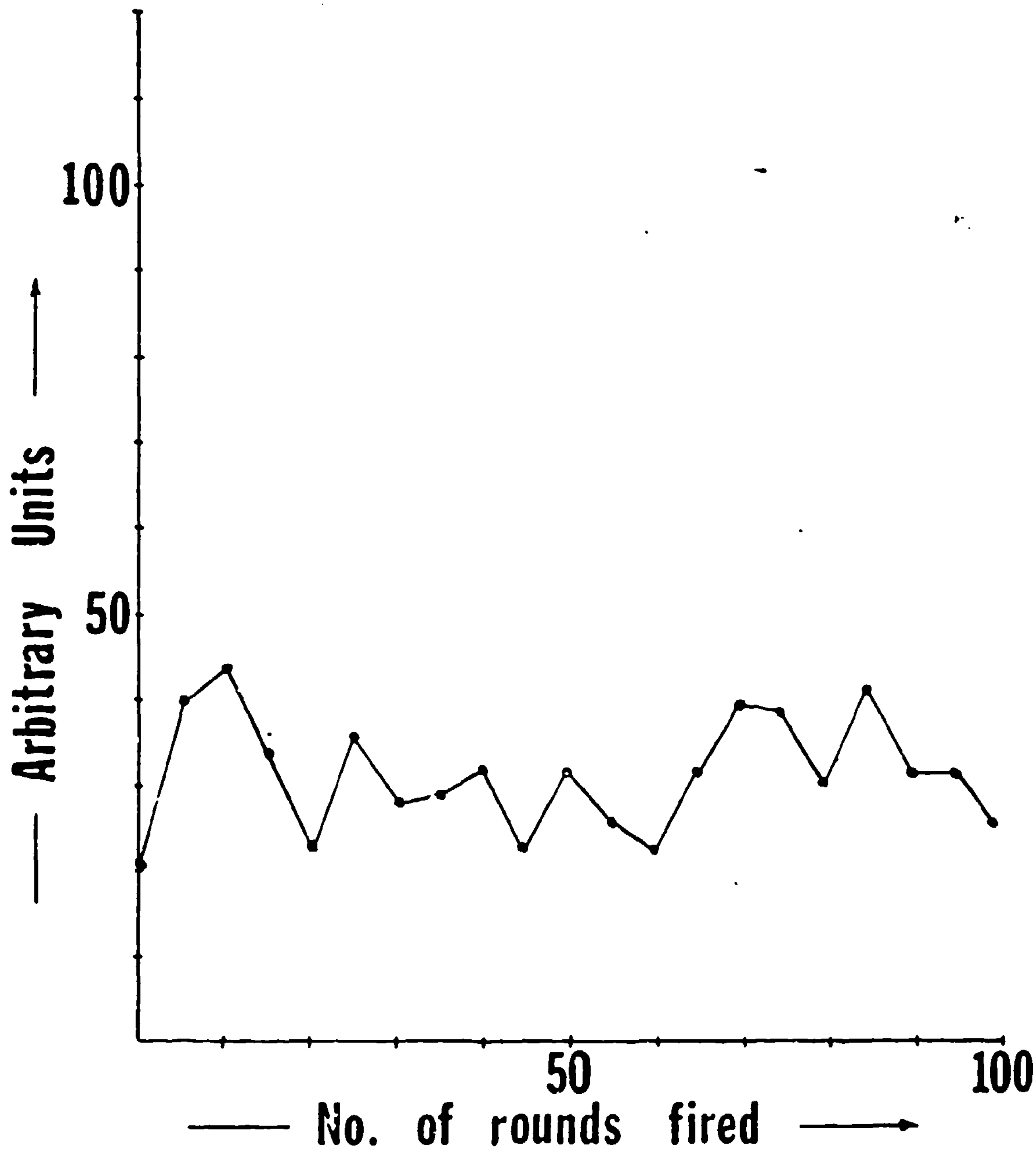

Figure 25. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 46.

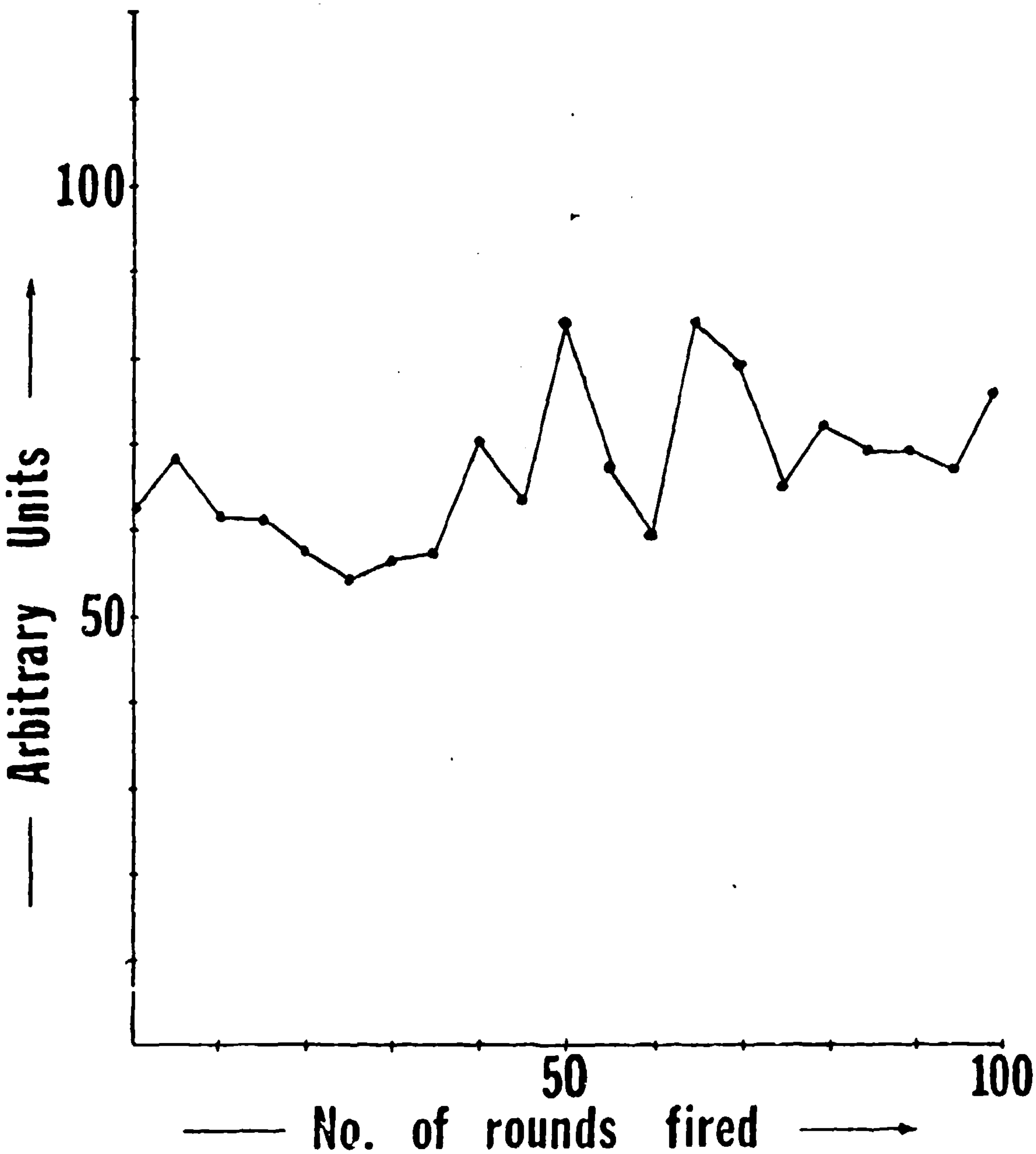

Figure 26. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 71.

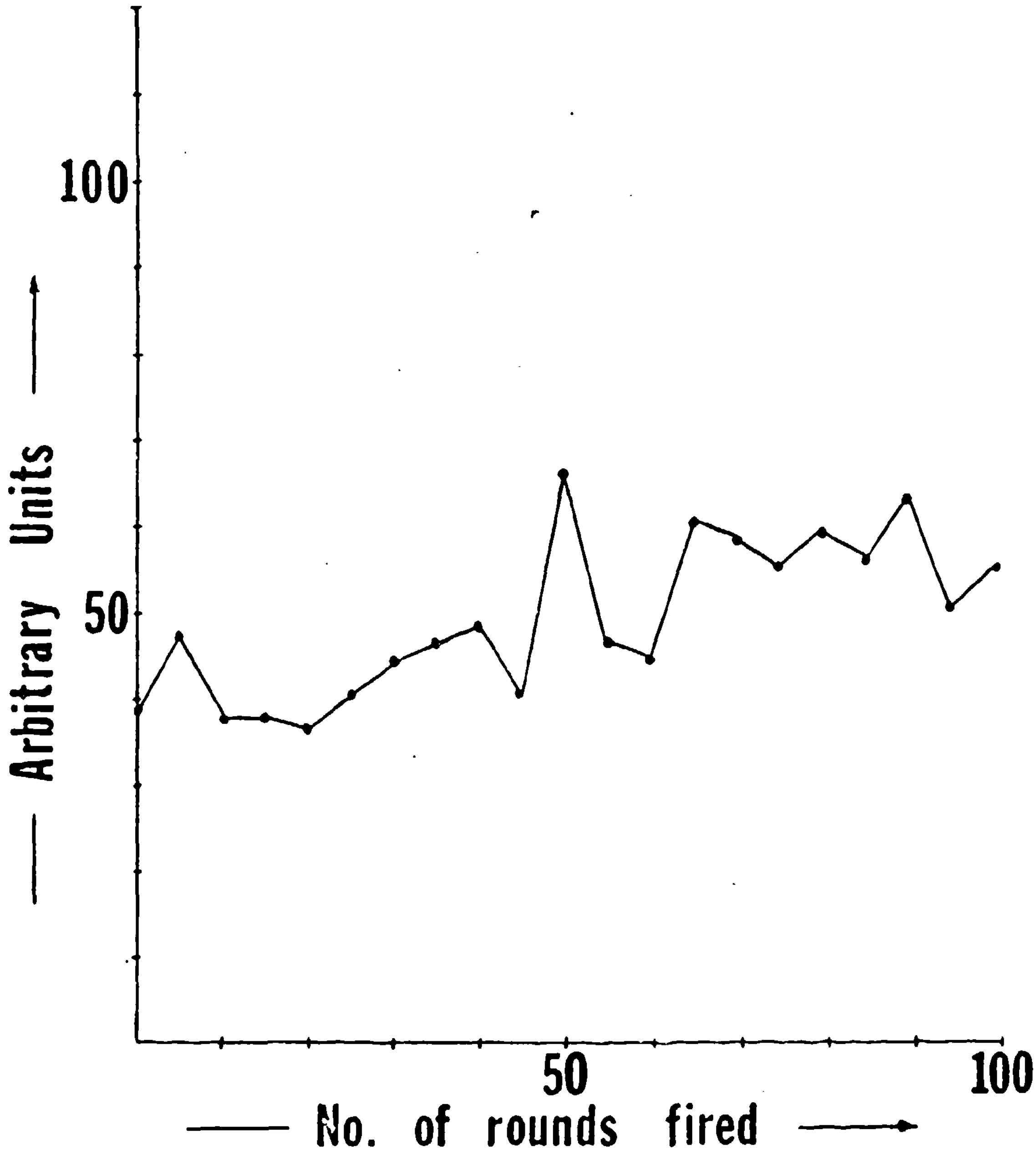

Figure 27. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 71.

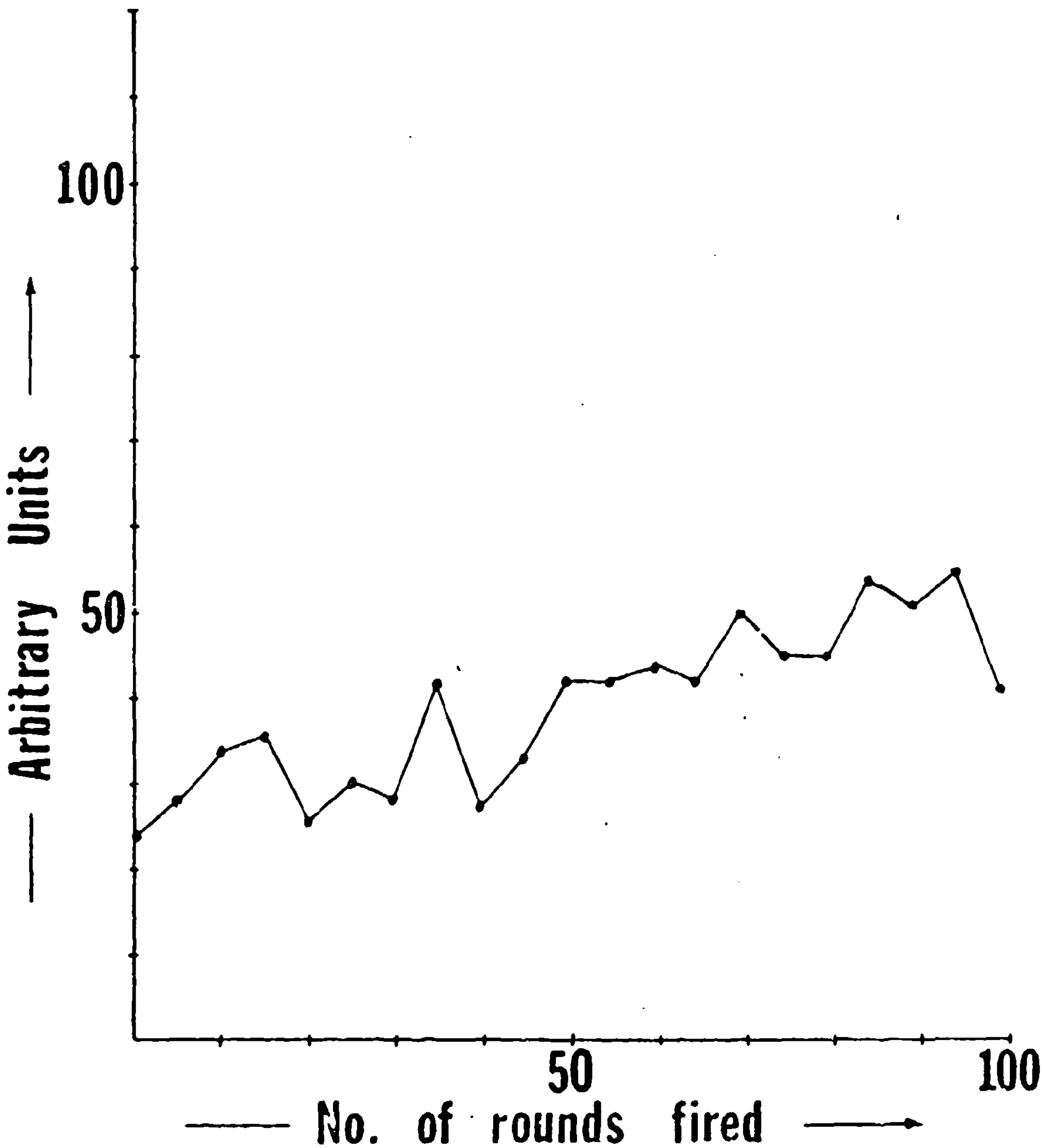

Figure 28. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 86.

c. Observations During Firing Tests.

It appeared the .357 ammunition left much cleaner chambers than the .38 Special ammunition.

Gun no. 95 was very difficult to operate in the course of firing 100 rounds. After 20 rounds, it was difficult to open and close the cylinder. After 39 rounds, it was necessary to tighten the screws on the frame. After 61 rounds, the trigger return would stick, disabling the cylinder latch. After 80 rounds, retighten screws and cylinder latch sticks. After 95 rounds, again necessary to retighten screws, and after 97 rounds the cylinder bolt latch was stuck.

Gun no. 98 (only 70 rounds shot) showed loosened screws after rounds 13 and 30. After the first 5 and 10 rounds, small metal flakes were observed chipping from the firing pin hole in the recoil plate.

Gun no. 71 required tightening of the cylinder latch screw after 25 rounds.

Gun no. 99 suffered from an unreliable trigger return action initially, causing the cylinder to lock. After 40 to 50 rounds it became harder to cock the hammer.

The engineer who handled the test firing noted in his report that all the guns tested seemed an order of magnitude above the Charter Arms weapons in ease of operation. Admittedly, this is a subjective observation.

d. Observations After Firing Tests.

Hardness Measurements on the Cross-sectioned Cylinders.

Table IV shows the hardness measurements on the cross-sectioned cylinders. Hardness is given in units on the Rockwell "C" scale.

TABLE IV

HARDNESS MEASUREMENTS

Gun no.	Avg. hardness	Std Deviation	No. Points Measured
10	34.5	0.5	12
43	32.4	1.2	12
89	37.9	1.7	12
98	38.0	0.9	12
99	33.2	4.5	15
19	29.2	1.8	12
46	36.3	0.9	12

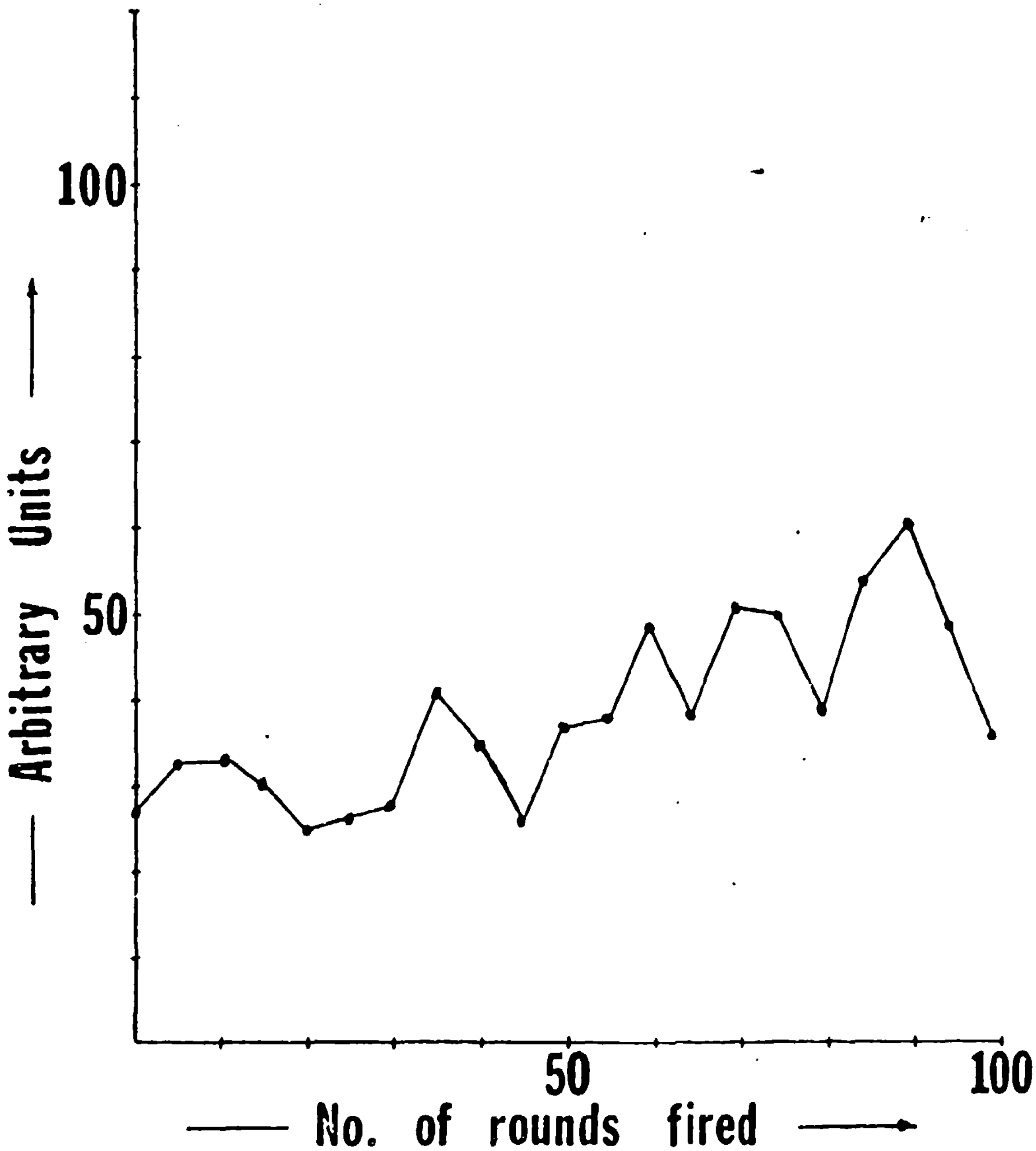

Figure 29. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 86.

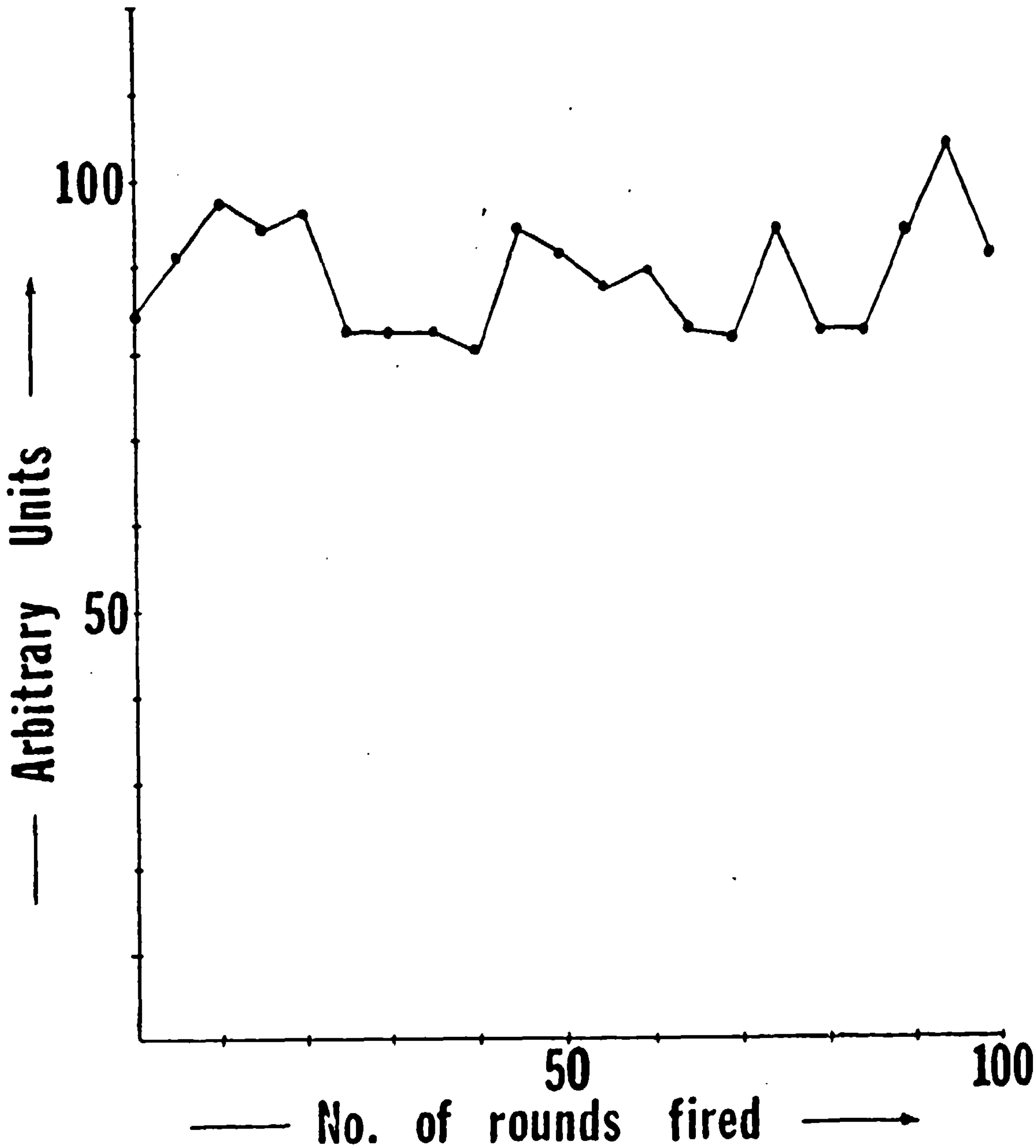

Figure 30. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 95.

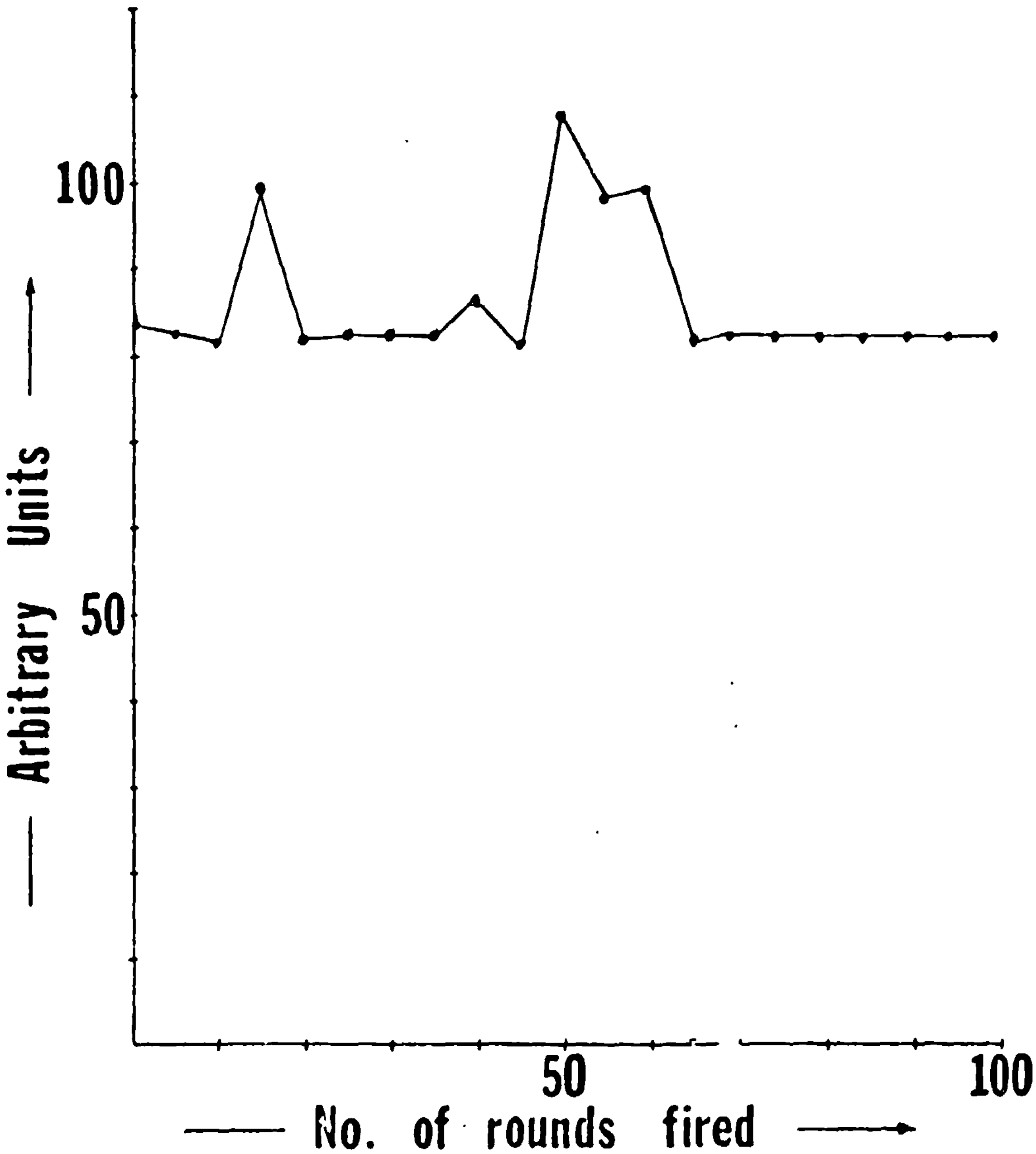

Figure 31. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 95.

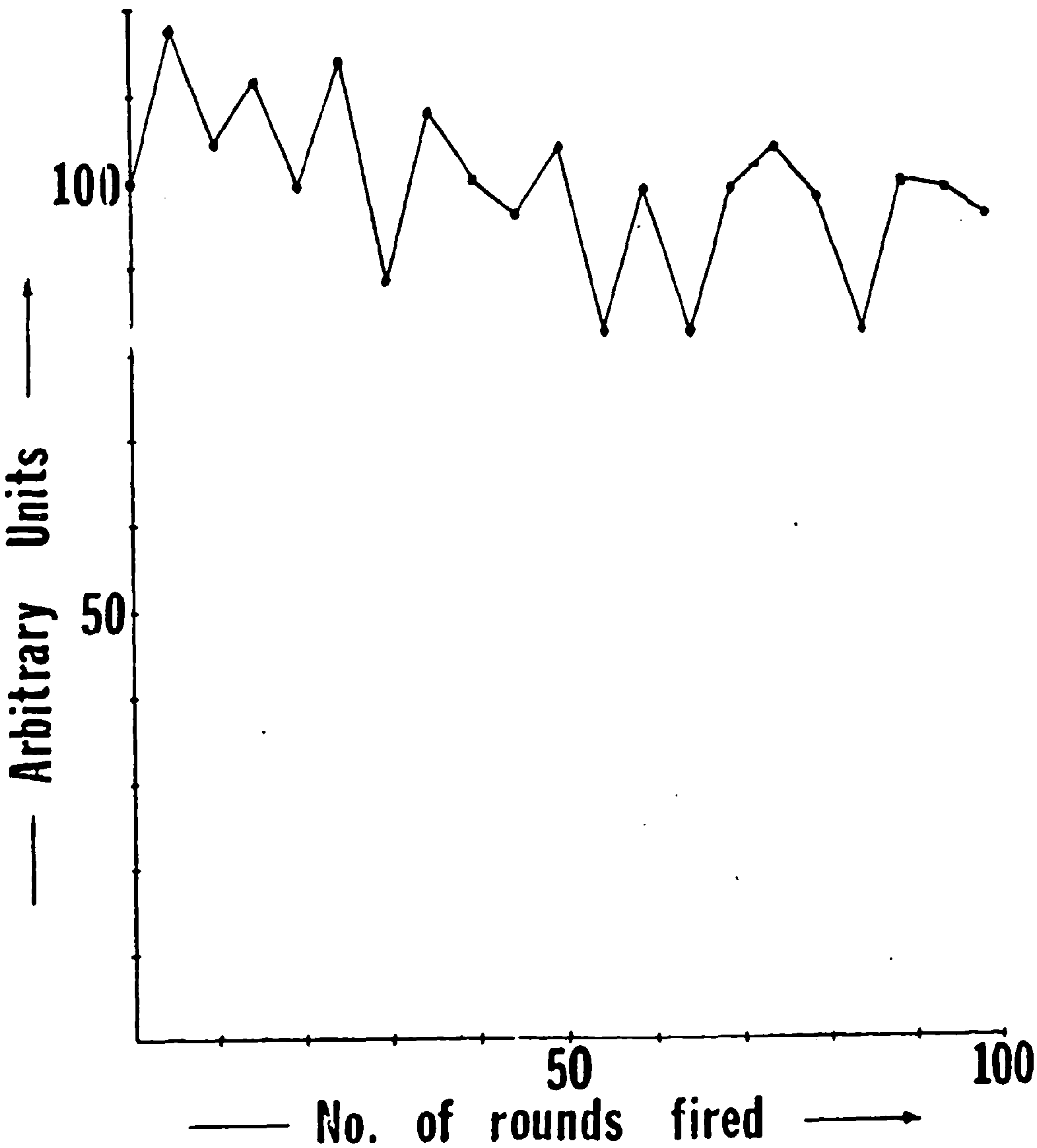

Figure 32. Detector Output vs. Rounds Fired for Athwart Scan of Gun no. 110.

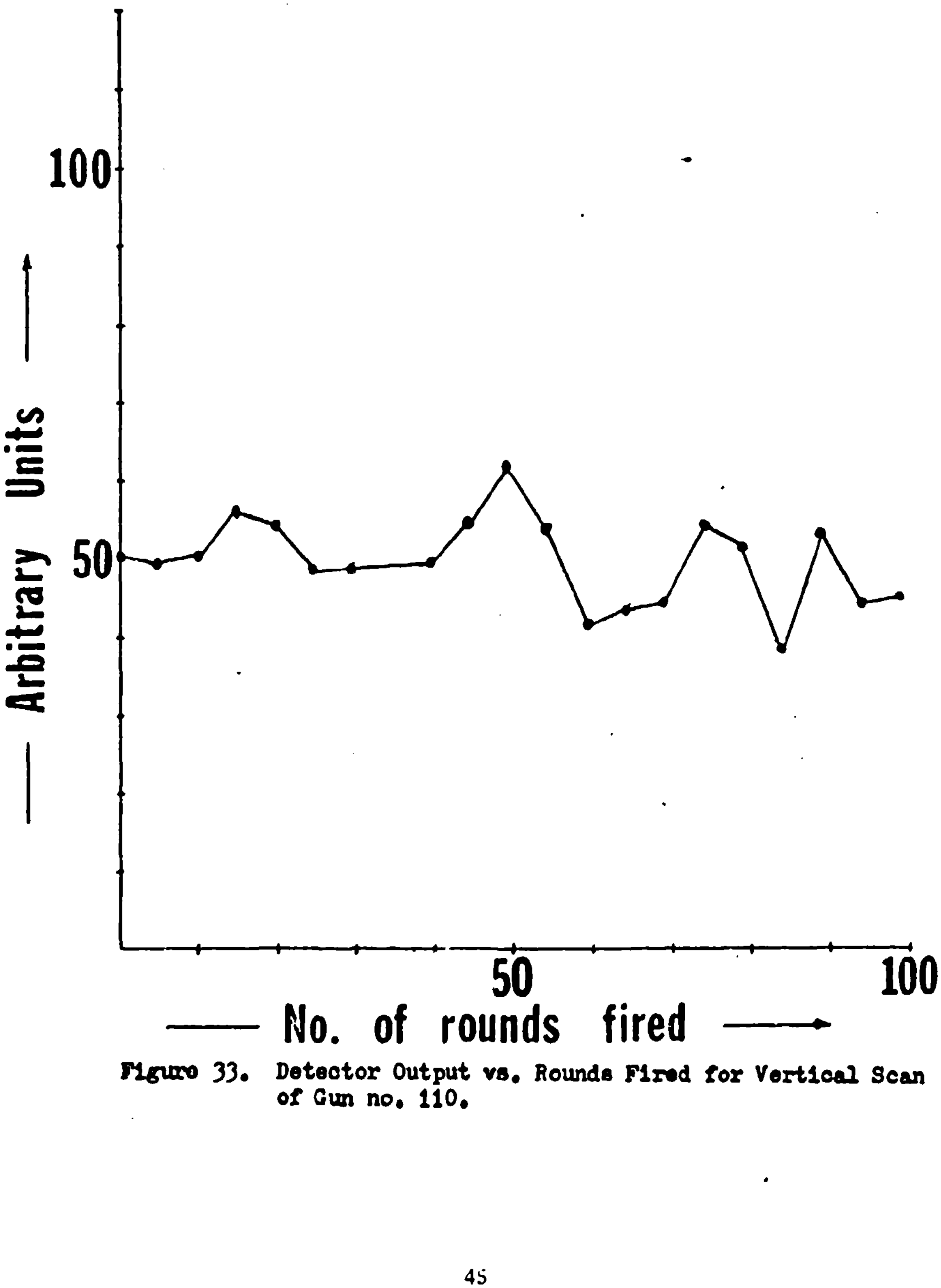

Figure 33. Detector Output vs. Rounds Fired for Vertical Scan of Gun no. 110.

TABLE IV (CONT'D)

Gun no.	Avg. hardness	Std Deviation	No. Points Measured
71	35.1	1.8	12
86	41.4	2.1	12
95	37.0	0.9	10
110	32.7	1.7	12

IV. ARMOR PLATE TESTS

a. Velocity Measurements.

Bullet velocity measurements were made using Ruger Police Service Six revolvers with 4 inch barrels (Model GF-84 and Model SDA-34). The ammunition used was Smith and Wesson .38 Special "+P" 158 grain jacketed hollow point and Smith and Wesson .357 Magnum 125 grain jacketed soft point. Bullet velocity was calculated from the time it took the bullet to travel a fixed distance between screens. The distance was defined by a rigid tubular casing with parallel ends and a precise length of 45.625"± .002". The tube diameter was 10 inches, more or less. Time interval was measured with a Hewlett Packard HP 5326A Timer-counter. Aluminum foil was taped over each end of the tube, to serve as foil screens. The detail construction was two pieces of aluminum foil separated by a piece of paper, and with a cardboard backing to provide rigidity. Two 1.5 volt dry cells were used to provide trigger signals. The gun muzzle was 20 inches from the front screen. Measurements were found to be much more consistent when a plywood baffle was placed between the gun and the front screen to protect the front screen from the muzzle blast. A 3/4ths inch hole in the baffle provided for undisturbed flight of the bullet. Table V shows the results of these measurements.

TABLE V

VELOCITY MEASUREMENTS

Round	Time (microseconds)	Velocity (ft/second)
.38 Special	4287.0	887
	4329.5	878
	4335.2	877
	4217.7	901
	4214.3	902

Average velocity = 889 ± 12

Round	Time (microseconds)	Velocity (ft/second)
.357 Magnum	2852.5	1333
	2724.3	1396
	2877.3	1321
	2737.1	1389
	2824.1	1346

Average velocity = 1357 ± 34

Consideration of propagation of errors yields the relation:

$$(\delta v/v)^2 = (\delta l/l)^2 + (\delta t/t)^2$$

where δv = error in velocity measurement
v = mean velocity
δt = error in time measurement
t = mean time
δl = error in distance measurement
l = mean distance

Using the following values:

	.38 Special	.357 Magnum
mean time	4277 μsec	2803 μsec
error in time	0.1 μsec	0.1 μsec
mean distance	45.625"	45.625"
error in dist.	0.1"	0.1"

We get

δv = 2 ft/sec for .38 Special

δv = 3 ft/sec for .357 Magnum

One can therefore conclude that the measured standard deviations on the velocities result from real differences in velocities of individual rounds, since the maximum measurement error is about an order of magnitude less in both cases.

b. Plate Tests.

Bullets were fired into steel and aluminum plates under various conditions. Two guns were used; the same ones used for the velocity measurements. The same ammunition was also used. The three types of plates tested were a) 7075-T6 aluminum, 0.25" thick, b) RHA (BHN 387) steel, 0.125" thick, and c) RHA (BHN 387) steel, 0.095" thick. The plates were tested at three different angles, (0°, 30°, and 60°). These angles are defined as the angle between the axis of the incoming bullet and the normal to the plate. The plates were supported along their sides by four ½" thick steel blocks which did not extend more than ¼" toward the center of the plate. The plates did not move upon impact. Each plate was shot only once. Three shots were made for each angle, each of the three types of plates, and each of the two guns. Thus a total of 54 plates were tested. After firing, the plates were returned to BRL for analysis.

Fracture was observed for only one particular combination of gun, angle, and plate type, (7075-T6 aluminum, 0.25" thick, at 0° for .357 Magnum ammunition). A spall type fracture which exhibits lamellar tearing in the rolled sheet occurred for all three plates impacted under these conditions. The spall/tear was about 1½" long in the rolling direction of the plate and half that wide in the transverse direction. It was not symmetric with respect to the point of impact.

Of the rest of the plates shot with .357 Magnum ammunition, those at angles of 0° and 30° were substantially dented while at 60° the deformation was slight. Deformation was also slight in all plates shot with the .38 Special "+P" ammunition except for the steel plates 0.095" thick at 0° and 30° where deformation was a bit more severe.

V. DISCUSSION AND CONCLUSIONS

Considering the static strain measurements, if one looks only at the data on the pressurized chambers (chamber no. 1 column in Tables II and III), Gun no. 43 appears to be the most solid .38 Special handgun and Gun no. 19 appears to be the most solid .357 Magnum. Looking at the plots, Gun no. 19 and Gun no. 95 show the least assymmetry in deformation, (remember Gun no. 95 has only five chambers). Temper this observation with the fact that Gun no. 95 showed several negative characteristics. It had one of the largest initial strains in chamber no. 1. (Only its companion model in .38 Special was comparable.) It was the only one to pop a strain gage off during firing (another possible indication of a large peak dynamic strain). It was also the only handgun to exhibit a large shift in behavior of chamber no. 1 comparing before firing with after firing. (Possibly a large residual stress change?)

The discrepancy between Gun no. 99 and Gun no. 98 is hard to understand since both are the same model. Nos. 98 and 95 show initial strains significantly larger than any of the others, but Gun no. 99 is low. R. Pond, Sr., of Marvalaud, who prepared the metallographic specimens, speculated there may be a problem in control of quench rate in the quench and temper operation, as he found some indication of slack quenching in the microstructure.

All the others seem to be more or less the same before and after firing.

One would conclude that Gun nos. 43 and 19 are the least deformable in their cylinders, and that there are some anomalies associated with Gun nos. 95, 98, and 99.

The unusually large standard deviation in hardness measurement on Gun no. 99 tends to support the speculation that something unusual (and inhomogeneous) is happening in the heat treatment.

The best overall behavior in the recoil plate measurements comes from Gun no. 46, which shows a relatively constant low level output. Next best would be Gun no. 86 and Gun no. 71 which also show low level outputs, but they are on the average slightly increasing. Third best would be Gun no. 43 with again a low level output, but increasing on the average more rapidly.

The observations during the firing tests speak for themselves.

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